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Environmental Assessment of the Alaskan Continental Shelf

Final Reports of Principal Investigators
Volume 14. Biological Studies

U.S. DEPARTMENT OF COMMERCE
National Oceanic & Atmospheric Administration
Office of Marine Pollution Assessment

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

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FINAL REPORT

THE EPIFAUNA OF THREE BAYS (PORT ETCHES, ZAIKOF BAY AND ROCKY BAY) IN PRINCE WILLIAM SOUND, ALASKA, WITH NOTES ON FEEDING BIOLOGY

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March 1980

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SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objectives of this study were to (1) obtain a qualitative and quantitative inventory of dominant epibenthic species within selected bays of Prince William Sound, and (2) make observations of food habits on selected species of invertebrates and fishes.

Twenty-eight stations have been established as a basis for a monitoring program in three bays of Prince William Sound — Port Etches (13 stations), Zaikof Bay (8 stations) and Rocky Bay (7 stations).

Information on the distribution and abundance of the major epifaunal invertebrates of the three study bays has been accumulated. Ten phyla are represented in the collection. The important groups, in terms of species were, in descending order of importance, Mollusca, Arthropoda (Crustacea), and Echinodermata. The important groups, in terms of biomass, in Port Etches, Zaikof Bay and Rocky Bay were Mollusca: 0.23, 1.84 and 3.29% in the three bays, respectively; Arthropoda: 36.26, 45.39 and 5.96%, respectively; and Echinodermata: 62.42, 50.40, and 86.93%, respectively.

Further seasonal data are essential. It is only when continuing information is available that biological assessment of the impact of oil spills on the benthic biota of these bays can be effectively accomplished.

Feeding data for the snow crab (*Chionoecetes bairdi*) and the sunflower sea star (*Pycnopodia helianthoides*) from the three bays are presented in this report. These data, in conjunction with similar data for these species in Prince William Sound, the Kodiak area and the northeast Gulf of Alaska, should contribute to a better understanding of the trophic role of these invertebrates, and permit assessment of the potential impact of oil spills on the two species.

The importance of deposit-feeding bivalves in the diet of snow crab, and bivalves and predatory/scavenger gastropods as food for the sunflower sea star is demonstrated for the three bays. Similar food regimes for these species have also been observed elsewhere. A high probability exists that hydrocarbons will enter crabs and sea stars *via* deposit feeding, predatory and scavenging molluscs. It is suggested that studies which examine the relationships between sediment, oil, prey species and predators be initiated.

The sampling of invertebrates and vertebrates using trawls, and stomach analyses of some of these organisms, has made it possible to better understand the epifaunal component of three Prince William Sound bays. Available data indicate adequate numbers of unique, abundant, and/or conspicuous species for monitoring environmental conditions in the three bays. A monitoring program should be based primarily on recruitment, growth, food habits and reproduction of the specific species.

INTRODUCTION

General Nature and Scope of Study

Activities connected with oil transport in Prince William Sound and the possible usage of Port Etches, Zaikof Bay and Rocky Bay as emergency anchorages for tankers, present a wide spectrum of potential dangers to the marine environment (see Olson and Burgess, 1967, for general discussion of marine pollution problems). Adverse effects on the environment of Prince William Sound cannot be assessed, or even predicted, unless background data are recorded prior to industrial development (see Lewis, 1970; Pearson, 1971, 1972, 1975, 1980; Nelson-Smith, 1973; Rosenberg, 1973, for discussions). Insufficient long-term information about a particular environment and the basic biology of species present can lead to erroneous interpretations of changes that might occur if the area becomes altered (see Pearson, 1971, 1972; Nelson-Smith, 1973; Rosenberg, 1973, for general discussions on benthic biological investigations in industrialized marine areas). Populations of benthic marine species may fluctuate over a time span of a few to as many as 30 or more years (Lewis, 1970).

Benthic organisms (primarily the infauna and sessile and slow-moving epifauna) are useful as indicator species because they tend to remain in place, typically react to long-range environmental changes, and by their presence, generally reflect the nature of the substratum. Consequently, the organisms of the infaunal benthos have frequently been chosen to monitor long-term pollution effects, and are believed to reflect the biological health of a marine area (see Pearson, 1971, 1972, 1975, 1980; and Rosenberg, 1973, for discussions on usage of benthic organisms for monitoring pollution). The presence of large numbers of benthic epifaunal species of actual or potential commercial importance (crabs, shrimps, fin fishes) in Prince William Sound, further dictates the necessity of understanding this benthic community since many commercial species feed on infaunal and small epifaunal residents of the benthos (see Zenkevitch, 1963; Feder *et al.*, 1980; and this report for a discussion of the interaction of commercial species and the benthos). Drastic changes in density of the benthos could affect the health and numbers of these fisheries organisms.

Effects of oil pollution on subtidal benthic organisms have been neglected until recently, and only a few studies conducted after serious oil spills have been published (Boesch *et al.*, 1974, for review; Kineman *et al.*, 1980). Thus, the lack of a broad data base elsewhere makes it difficult to predict the effects of oil-related activity on the benthos of Prince William Sound. However, data from environmental assessment activities on the Alaska shelf and within Prince William Sound should make it possible to identify species that might bear closer scrutiny now that tankers are operational in the Sound (for reviews and data summaries from Alaskan waters, see Schaefers *et al.*, 1955; Anonymous, 1964; Hitz and Rathjen, 1965; Rosenberg, 1972; Feder *et al.*, 1973, 1980, in press; Hughes, 1974; Powell *et al.*, 1974; Bakus and Chamberlain, 1975; Feder and Mueller, 1975; Ronholt *et al.*, 1976; Jewett, 1977; Feder and Jewett, 1977, 1980, in press; Feder and Paul, 1978, 1980; Feder and Matheke, 1979; Jewett and Powell, 1979).

Experience in pollution-prone areas of England (Smith, 1968), Scotland (Pearson, 1980), and California (Straughan, 1971) suggests that at the completion of an initial exploratory study, selected stations should be examined regularly on a long-term basis to determine any changes in species composition, diversity, abundance, and biomass. Such long-term data acquisition should make it possible to differentiate between normal ecosystem variation and pollutant-induced biological alteration. An intensive investigation of the benthos of Prince William Sound, as well as its bays, is essential to an understanding of trophic interactions there and the potential changes that could take place now that oil-related activities have been initiated. An intensive benthic biological program in the northeast Gulf of Alaska (NEGOA) has emphasized the importance of a qualitative and quantitative inventory of prominent species of the benthic infauna and epifauna (Jewett and Feder, 1976; Feder and Matheke, 1979).

Relevance to Problems of Petroleum Development

Data showing the effects of oil on most subtidal benthic invertebrates are fragmentary (Nelson-Smith, 1973). The Tanner or snow crab, *Chionoecetes bairdi*, is a conspicuous inhabitant of Prince William Sound and its bays. Laboratory experiments with this species have shown that post-molt individuals lose most of their legs after exposure to Prudhoe Bay crude oil. Obviously this aspect of the biology of the snow crab must be considered in the continuing assessment of this benthic species in Prince William Sound (Karinen and Rice, 1974). Little other direct data, based on laboratory experiments, are available for subtidal benthic species (see Nelson-Smith, 1973, for review). Experimentation on toxic effects of oil on other common members of the subtidal benthos of Prince William Sound should be strongly encouraged for the near future. In addition, the potential effects of the loss of sensitive species to the trophic structure in Prince William Sound must be examined. The above problems can best be addressed by examination of benthic food studies published by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) (Smith *et al.*, 1976; Feder and Jewett, 1977, 1980, in press; Feder and Paul, 1980; Feder *et al.*, in press).

A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (see Rhoads, 1974, for review). He describes a diesel-fuel oil spill that resulted in oil becoming adsorbed on sediment particles which in turn caused death in deposit feeders living on sublittoral muds. Bottom stability was altered with the death of these organisms, and a new complex of species became established in the altered substratum. Many common members of the infauna of the Gulf of Alaska are deposit feeders; thus, oil-related mortality of these species could result in a changed near-bottom sedimentary regime with alteration of species composition there. In addition, commercially important snow crab and some bottom fishes use deposit feeders as food (Feder and Jewett, 1977, 1980, in press; Feder and Paul, 1980; Feder *et al.*, in press); thus contamination of the bottom by oil might indirectly affect commercial species in Prince William Sound.

Increased tanker traffic through Hinchinbrook Entrance, now that Port Valdez is an operational oil port, necessitates further study of the epibenthic system in Prince William Sound.

CURRENT STATE OF KNOWLEDGE

Limited information is available on the distribution and biology of the epifauna of Prince William Sound (Feder *et al.*, 1973; Feder and Paul, 1978; Feder and Matheke, 1980); although compilation of relevant data for the Gulf of Alaska are available (Hitz and Rathjen, 1965; Rosenberg, 1972; Hughes, 1974; AEIDC, 1975; Jewett and Feder, 1976; Feder and Jewett, in press; Feder *et al.*, in press). The exploratory trawl surveys of the National Marine Fisheries Service are the most extensive investigations of the benthic epifauna but caution must often be exercised in interpreting data from these surveys. The results, each directed toward different groups and/or species, are not typically comparable due to the differences in gear and sampling effort from one cruise to another.

STUDY AREA

Benthic trawl stations were occupied in three Prince William Sound bays. Port Etches is located on the southwest side of Hinchinbrook Island while Zaikof Bay and Rocky Bay are located on the northeast side of Montague Island (Fig. 1).

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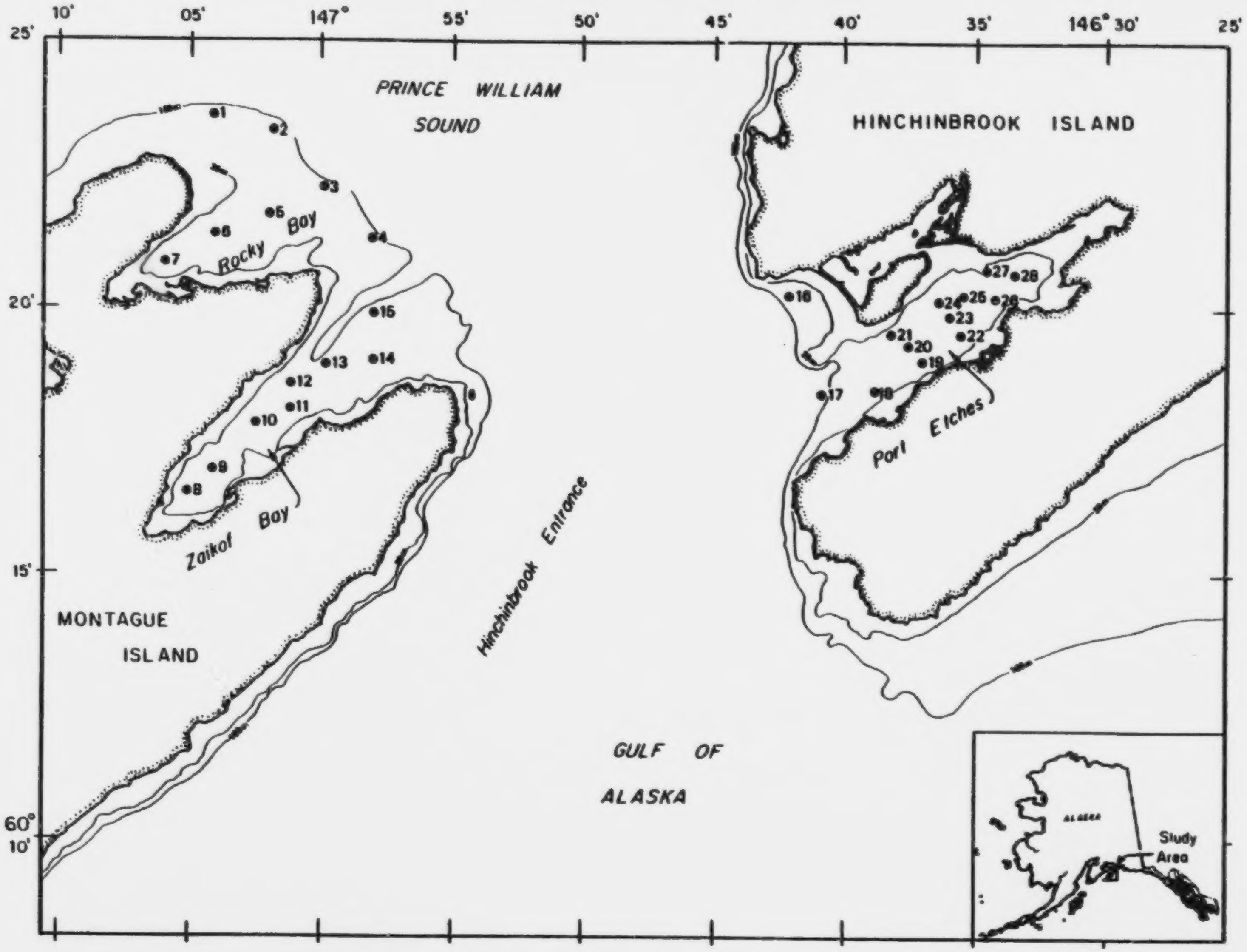

PRINCE WILLIAM SOUND
HINCHINBROOK ISLAND
MONTAGUE ISLAND
Rocky Bay
Zaikof Bay
Port Etches
Hinchinbrook Entrance
GULF OF ALASKA
Study Area
ALASKA
10'
05'
147°
55'
50'
45'
40'
35'
146° 30'
25'
20'
15'
60° 10'
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Figure 1. Trawl station locations in Port Etches, Zaikof Bay and Rocky Bay, July/August 1978

SOURCES, METHODS AND RATIONALE OF DATA COLLECTON

Stations were occupied in Port Etches, Zaikof Bay and Rocky Bay, Prince William Sound (Fig. 1; Appendix Table I) from 28 July to 7 August 1978 on the M/V *Searcher*. Material was collected at 28 stations. Tows were usually 15 minutes in duration, and made with a small otter trawl (try net) with a 6.1-m horizontal opening. Samples were taken to a maximum depth of approximately 100 m. All organisms were sorted on shipboard, given tentative identifications and counted. Abundant species were weighed. Aliquot samples of individual species were preserved in buffered, 10% formalin, and labeled for final identification at the University of Alaska.

Biomass per unit area (g/m^2) is calculated as follows: $\frac{W}{Tw(Dx1000)}$; where W = weight (grams), Tw = width of trawl opening (meters), and (D) is distance fished (kilometers x 1000). The data base for all calculations of biomass per m^2 in the present report have been submitted to the National Oceanographic Data Center (NODC).

After final identification, all invertebrates were assigned code numbers (Mueller, 1975) to facilitate data analysis by computer. Representative samples of invertebrates are stored at the Institute of Marine Science, University of Alaska, Fairbanks, Alaska. Voucher samples are deposited at the California Academy of Sciences.

The major limitation of the survey was that imposed by the selectivity of the otter trawl used. In addition, rocky-bottom areas could not be sampled since otter trawls of the type used can only be fished on relatively smooth bottoms.

Stomach contents of the snow crab (*Chionoecetes bairdi*), the sunflower sea star (*Pycnopodia helianthoides*), and several fish species were analyzed. All stomachs were examined by the frequency of occurrence method. Seventy-six percent of all snow crab examined were less than 40 mm in carapace width. Since food used by crab < 40 mm, as well as crab > 40 mm were similar, all sizes were combined when reporting the data.

Exoskeletons of snow crabs were identified as (1) recently molted, (2) newshell, (3) oldshell, and (4) very oldshell (Donaldson, 1977).

RESULTS

Port Etches

Distribution, biomass, and abundance

A total of 13 stations was sampled by trawl in Port Etches, covering a distance of 12.6 km (Table 1). The average epifaunal invertebrate biomass for all stations sampled was 0.85 g/m^2.

Taxonomic analysis of epifaunal invertebrates from Port Etches delineated 6 phyla, 9 classes, 24 families, 30 genera and 39 species (Table II). Arthropoda (Crustacea), Mollusca and Echinodermata dominated with 22, 8, and 4 species, respectively (Table II). Echinodermata accounted for 62.4% of the total invertebrate biomass (Table III). The family Asteriidae made up 59.2% of this biomass (Table IV). The leading species, in terms of biomass, in this family was the sunflower sea star, *Pycnopodia helianthoides*, (Table V). Arthropoda accounted for 36.3% of the total invertebrate biomass (Table III). The families Pandalidae and Majidae made up 33.8% of this biomass (Table IV). The leading species in each of these families, respectively, were the pink shrimp (*Pandalus borealis*) and the snow crab (*Chionoecetes bairdi*) (Table V). Although eight species of Mollusca were represented, these species only accounted for 0.23% of the total invertebrate biomass (Tables II, III).

Abundance data for the dominant organisms in Port Etches are also listed in Tables III-V.

Feeding

The stomachs of snow crab, *Chionoecetes bairdi*, from Port Etches mainly contained bivalves (*Nucula tenuis* and *Nuculana* spp.), gastropods, juvenile snow crab (*C. bairdi*), unidentified plant and animal material, and sediment (Table VI).

Pycnopodia helianthoides preyed almost entirely on bivalves, gastropods and crustaceans. A bivalve (*Nuculana fossa*) and a gastropod (*Mitrella gouldi*) were the dominant organisms preyed upon. Other foods of lesser

Text continued on page 16

TABLE I

TOTAL EPIFAUNAL INVERTEBRATE BIOMASS FROM BENTHIC TRAWLING ACTIVITIES IN PORT ETCHES, ZAIKOF BAY AND ROCKY BAY: JULY/AUGUST 1978

Port Etches			Zaikof Bay			Rocky Bay		
Weight (kg)	Distance fished (km)	g/m^2	Weight (kg)	Distance fished (km)	g/m^2	Weight (kg)	Distance fished (km)	g/m^2
65.48	12.62	0.851	19.72	8.12	0.398	52.18	6.88	1.243

All Bays		
Weight (kg)	Distance fished (km)	g/m^2
137.39	27.62	0.815

TABLE II

A LIST OF SPECIES TAKEN BY TRAWL FROM PORT ETCHES, HINCHINBROOK ISLAND, ALASKA, JULY/AUGUST 1978

- Phylum Cnidaria
  - Class Anthozoa
    - Family Pennatulidae
      - *Ptilosarcus gurneyi* (Gray)
    - Family Actinostolidae
      - *Stomphia coccinea* (O. F. Müller)
    - Family Metridiidae
      - *Metridium senile* (Linnaeus)

- Phylum Annelida
  - Class Polychaeta
    - Family Nephtyidae
      - *Nephtys* spp.

- Phylum Mollusca
  - Class Pelecypoda
    - Family Nuculanidae
      - *Nuculana fossa* Baird
    - Family Astartidae
      - *Astarte borealis* Schumacher
    - Family Cardiidae
      - *Clinocardium ciliatum* (Fabricius)
    - Family Thraciidae
      - *Thracia* spp.
  - Class Gastropoda
    - Family Dorididae
    - Family Arminidae
      - *Armina californica* (Cooper)
  - Class Cephalopoda
    - Family Octopodidae
      - *Octopus* sp.

- Phylum Arthropoda
  - Class Crustacea
    - Family Balanidae
      - *Balanus* spp.
      - *Balanus crenatus* Pilsbury
      - *Balanus hesperius* Pilsbury
    - Order Decapoda
      - Family Pandalidae
        - *Pandalus borealis* Kröyer
        - *Pandalus platyceros* Brandt
        - *Pandalus hypsinotus* Brandt
        - *Pandalus danae* Stimpson
        - *Pandalopsis dispar* Rathbun

TABLE II

CONTINUED

Phylum Arthropoda (cont'd)
        Family Hippolytidae
            Eualus biunguis Rathbun
        Family Crangonidae
            Crangon dalli Rathbun
            Crangon communis Rathbun
            Argis dentata (Rathbun)
        Family Paguridae
            Pagurus ochotensis Brandt
            Pagurus capillatus (Benedict)
            Elassochirus tenuimanus (Dana)
            Labidochirus splendescens (Owen)
        Family Majidae
            Oregonia gracilis (Dana)
            Hyas lyratus Dana
            Chionoecetes bairdi Rathbun
        Family Cancridae
            Cancer magister Dana
        Family Atelecyclidae
            Telmessus cheiragonus (Tilesius)

Phylum Echinodermata
    Class Asteroidea
        Family Asteropidae
            Dermasterias imbricata (Grube)
        Family Asteriidae
            Pycnopodia helianthoides (Brandt)
        Family Strongylocentrotidae
            Strongylocentrotus droebachiensis (O. F. Müller)

    Class Ophiuroidea
        Family Ophiuridae
            Ophiura sarsi Lütken

Phylum Urochordata
    Class Ascidiacea
            unidentified sp.

TABLE III

NUMBER, WEIGHT AND BIOMASS OF MAJOR EPIFAUNAL INVERTEBRATE PHYLA OF PORT ETCHES, ZAIKOF BAY AND ROCKY BAY, JULY/AUGUST 1978

	Number of organisms			Weight (g)			Percent of total weight*			Mean grams per m^2		
Phylum	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky
Porifera	-	-	-	-	130	1001	-	0.66	1.92	-	0.003	0.024
Cnidaria	53	6	8	690	309	519	1.05	1.57	0.99	0.009	0.006	0.012
Mollusca	2267	193	164	153	362	1718	0.23	1.84	3.29	0.002	0.007	0.041
Arthropoda (Crustacea)	2271	955	309	23742	8953	3109	36.26	45.39	5.96	0.308	0.181	0.074
Brachiopoda	-	-	45	-	-	196	-	-	.38	-	-	0.005
Echinodermata	184	58	13294	40870	9940	45361	62.42	50.40	86.93	0.531	0.201	1.081
Total	5275	1212	13775	65455	19694	51904	99.96	99.86	99.46	0.853	0.399	1.237

---

*See Table I for data on total epifaunal biomass for each area.

TABLE IV

NUMBER, WEIGHT AND BIOMASS OF MAJOR EPIFAUNAL INVERTEBRATE FAMILIES OF PORT ETCHES, ZAIKOF BAY AND ROCKY BAY, JULY/AUGUST 1978

	Number of organisms			Weight (g)			Percent of total weight			Mean grams per m^2		
Families	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky
Virgularidae	-	5	-	-	129	-	-	0.66	-	-	0.002	-
Pennatulidae	50	-	-	550	-	-	0.84	-	-	0.006	-	-
Metridiidae	2	1	-	120	170	-	0.18	0.86	-	0.001	0.003	-
Cardiidae	-	17	-	-	124	-	-	0.63	-	-	0.002	-
Pandalidae	2419	412	82	19600	6057	537	29.93	30.71	1.03	0.254	0.122	0.013
Crangonidae	69	86	45	489	373	145	0.75	1.89	0.28	0.006	0.007	0.003
Paguridae	16	29	53	323	192	534	0.49	0.97	1.02	0.004	0.004	0.013
Majidae	175	59	59	2552	1750	1805	3.90	8.87	3.46	0.033	0.035	0.043
Cancridae	1	5	1	600	408	5	0.92	2.07	0.01	0.008	0.008	<0.001
Asteriidae	92	8	11	38755	6623	1255	59.20	33.58	2.40	0.503	0.134	0.030
Gorgonocephalidae	-	24	50	-	2986	8290	-	15.14	15.89	-	0.060	0.197
Ophiuridae	80	2	12326	375	1	13631	0.57	<0.01	26.12	0.005	<0.001	0.325
Synallactidae	-	1	313	-	67	17920	-	.34	34.34	-	0.001	0.427
Total	2904	648	12941	63364	18880	44122	96.77	95.72	84.55	0.823	0.381	1.051

TABLE V

NUMBER, WEIGHT AND BIOMASS OF MAJOR EPIFAUNAL SPECIES FROM PORT ETCHES, ZAIKOF BAY AND ROCKY BAY, JULY/AUGUST 1978

	Number of organisms			Weight (g)			Percent of total weight			Mean grams per m^2		
Species	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky	Etches	Zaikof	Rocky
Pandalus borealis	2327	112	11	18110	1243	80	27.66	6.30	0.15	0.235	0.025	0.002
Pandalus hypsinotus	62	280	48	1270	4745	380	1.94	24.06	0.73	0.016	0.096	0.009
Argis dentata	21	34	7	318	222	45	0.48	1.13	0.09	0.004	0.004	0.001
Chionoecetes bairdi	169	52	26	2461	1690	390	3.76	8.57	0.75	0.032	0.034	0.009
Cancer magister	1	2	1	600	405	5	0.92	2.05	0.01	0.008	0.008	<0.001
Pycnopodia helianthoides	92	7	3	38755	6198	460	59.19	31.43	0.88	0.503	0.125	0.011
Gorgonocephalus caryi	-	24	50	-	2986	8290	-	15.14	15.89	-	0.060	0.197
Ophiura sarsi	80	2	12326	375	1	13631	0.57	0.01	26.12	0.005	<0.001	0.325
Bathyphlotes sp.	-	1	313	-	67	17920	-	0.34	34.34	-	0.001	0.427
Total	2752	463	12785	61889	17557	41201	94.53	89.01	78.95	0.804	0.354	0.982

TABLE VI

PERCENT FREQUENCY OF OCCURRENCE OF FOOD ITEMS FOUND IN STOMACHS OF *CHIONOECETES BAIRDI* FROM PORT ETCHES, ZAIKOF BAY AND ROCKY BAY, JULY/AUGUST 1978
N = NUMBER OF STOMACHS

	Port Etches			Zaikof Bay			Rocky Bay		
Food item*	Occurrence	% Stomachs w/food (N=23)	% Total stomachs (N=25)	Occurrence	% Stomachs w/food (N=9)	% Total stomachs (N=15)	Occurrence	% Stomachs w/food (N=12)	% Total stomachs (N=15)
Unidentified plant material	6	26	24	2	22	13	1	8	7
Foraminifera	4	17	16	2	22	13	6	50	40
Hydrozoa	-	-	-	-	-	-	-	-	-
Polychaeta (segmented worm)	-	-	-	-	-	-	8	67	53
Bivalvia (clam)	5	22	20	4	44	27	2	17	13
Nucula tenuis (clam)	19	83	76	-	-	-	-	-	-
Nuculanidae (clam)	-	-	-	4	44	27	-	-	-
Nuculana sp. (clam)	10	43	40	1	22	7	-	-	-
Axinopsida sp. (clam)	-	-	-	2	44	13	-	-	-
Axinopsida serricata (clam)	2	9	8	-	-	-	-	-	-
Macoma sp. (clam)	1	4	4	-	-	-	-	-	-
Gastropoda (snail)	11	48	44	-	-	-	-	-	-
Solariella sp. (snail)	-	-	-	-	-	-	2	17	13
Alvinia sp. (snail)	5	22	20	-	-	-	-	-	-
Skeneopsis sp. (snail)	1	4	4	-	-	-	-	-	-
Scaphopoda (tusk shells)	5	22	20	-	-	-	1	8	7
Crab remains	2	9	8	-	-	-	-	-	-
Shrimp remains	4	17	16	1	11	7	-	-	-
Crustacea	1	4	4	-	-	-	1	8	7
Pagurus sp. (hermit crab)	-	-	-	-	-	-	1	8	7
Chionoecetes bairdi (snow crab)	7	30	28	1	11	7	1	8	7
Ophiuridea (brittle star)	-	-	-	-	-	-	7	58	47
Pisces (fish)	1	4	4	-	-	-	4	33	27
Unidentified animal material	23	100	92	9	100	80	12	100	80
Sediment	21	91	84	9	100	80	10	83	67
Empty stomachs	2	9	8	2	44	13	3	25	20
Pollutants	-	-	-	2	44	13	1	8	7

*Lowest level of identification.

importance consumed by *P. helianthoides*, in order of diminishing frequency, were a bivalve (*Psephidia lordi*) and gastropods (*Solariella varicosa*, *Nassarius mendicus*, *Solariella obscura*, and *Alvinia compacta*) (Table VII).

Polychaetes, bivalves, crustaceans and fish remains were the main organisms consumed by the rex sole, *Glyptocephalus zachirus* (Appendix Table II). Flathead sole, *Hippoglossoides elassodon*, contained unidentified animal material, bivalves, crustaceans and fishes. Rock sole, *Lepidopsetta bilineata*, contained polychaetes, bivalves and crustaceans. Yellowfin sole, *Limanda aspera*, contained unidentified animal material, bivalves and crustaceans. Shortfin eelpout, *Lycodes brevipes*, contained unidentified animal material, polychaetes, bivalves and crustaceans. Sediment was also dominant in the stomachs of the above species.

Since a limited number of samples were available, some species are not included in Appendix Table II. However, comments on prey items are included here. Arrowtooth flounder, *Atheresthes stomias*, contained unidentified animal material, crustaceans and fishes. Walleye pollock, *Theragra chalcogramma*, contained unidentified animal material and crustacean remains. Snail fish, *Liparis* sp., contained unidentified animal material and crustacean remains.

Zaikof Bay

Distribution, biomass and abundance

A total of 8 stations was sampled by trawl in Zaikof Bay, covering a distance of 8.1 km (Table 1). The average epifaunal invertebrate biomass for all stations sampled was 0.40 g/m^2.

Taxonomic analysis of epifaunal invertebrates from Zaikof Bay delineated 11 phyla, 18 classes, 52 families, 64 genera, and 78 species (Table VIII). Mollusca, Arthropoda (Crustacea), and Echinodermata dominated with 27, 24, and 12 species, respectively (Table VIII). Echinodermata accounted for 50.4% of the total invertebrate biomass (Table III). The families Asteriidae and Gorgonocephalidae made up 48.7% of this biomass (Table IV). The leading species, in terms of biomass, in each of these families,

Text continued on page 22

TABLE VII

PYCNOPODIA HELIANTHOIDES STOMACH CONTENTS

Port Etches (no. examined [N] = 90; no. with food [NF] = 73)
Zaikof Bay (N = 2; NF = 1)
Rocky Bay (N = 3; NF = 2)

Stomach contents	Total frequency of occurrence	% frequency of occurrence: Stomachs w/food (NF = 76)	% frequency of occurrence: Total stomachs (N = 95)
Plant remains	1	1	1
Brown algae	2	3	2
Scyphozoa	1	1	1
Polychaeta (segmented worm)	1	1	1
Bivalvia (clams)	2	1	2
Nucula tenuis (clam)	4	5	4
Nuculana fossa (clam)	54	71	57
Yoldia sp. (clam)	1	1	1
Mytilus edulis (clam)	3	4	3
Tellina nuculoides (clam)	1	1	1
Psephidia lordi (clam)	12	16	13
Pandora filosa (clam)	2	3	2
Pandora grandis (clam)	1	1	1
Clinocardium californiense (cockle)	1	1	1
Cardiomya pectinata (clam)	2	3	2
Gastropoda (snail)	2	3	2
Trochiidae (snail)	1	1	1
Solariella sp. (snail)	3	4	3
Solariella obscura (snail)	5	7	5
Solariella varicosa (snail)	7	9	7
Margarites pupillus (snail)	1	1	1
Littorina sp. (snail)	1	1	1
Alvinia compacta (snail)	5	7	5
Natica clausa (snail)	2	3	2
Mitrella gouldi (snail)	23	30	24
Nassarius mendicus (snail)	7	9	7
Olivella baetica (snail)	1	1	1
Oenopota sp. (snail)	5	7	5
Propebela sp. (snail)	2	3	2
Turbonilla sp. (snail)	2	3	2
Cylichna alba (snail)	4	5	4
Balanus sp. (barnacle)	1	1	1
Balanus crenatus (barnacle)	2	1	2
Crab remains	2	3	2
Pagurus ochotensis (hermit crab)	1	1	1
Chionoecetes bairdi (snow crab)	2	3	2
Cancer magister (Dungeness crab)	1	1	1
Cancer oregonensis (crab)	1	1	1
Ophiuroidea (brittle star)	1	1	1
Unidentifiable digested material	11	14	12

TABLE VIII

A LIST OF SPECIES TAKEN BY TRAWL FROM ZAIKOF BAY, MONTAGUE ISLAND, ALASKA JULY/AUGUST 1978

- Phylum Porifera
  - Class Demospongia
    - Family Suberitidae
      - *Suberites suberea* Lambe
      - unidentified sp.

- Phylum Cnidaria
  - Class Hydrozoa
    - unidentified sp.

  - Class Anthozoa
    - Family Virgularidae
      - *Stylatula gracile* (Gabb)
    - Family Metridiidae
      - *Metridium senile* (Linnaeus)

- Phylum Rhynchocoela

- Phylum Annelida
  - Class Polychaeta
    - Family Polynoidae
      - *Eunoe depressa* Moore
    - Family Maldanidae
    - Family Nereidae
      - *Nereis* sp.
    - Family Sabellidae
      - *Pseudopotamilla reniformis* (Leuckhart)
    - Family Serpulidae
      - *Crucigera zygophora* (Johnson)

- Phylum Mollusca
  - Class Polyplacophora
    - Family Ischnochitonidae
      - *Ischnochiton trifidus* (Berry)

  - Class Bivalvia
    - Family Nuculanidae
      - *Nuculana fossa* Baird
      - *Yoldia amygdalea* Valenciennes
    - Family Pectinidae
      - *Chlamys rubida* Hinds
    - Family Anomiidae
      - *Pododesmus macrochisma* Deshayes
    - Family Astartidae
      - *Astarte borealis* Schumacher
      - *Astarte alaskensis* Dall

TABLE VIII

CONTINUED

- Phylum Mollusca (cont'd)
    - Family Cardiidae
        - *Clinocardium ciliatum* (Fabricius)
        - *Clinocardium fucanum* (Dall)
        - *Clinocardium californiense* (Deshayes)
        - *Serripes groenlandicus* (Bruguière)
    - Family Hiatellidae
        - *Hiatella arctica* (Linnaeus)
  - Class Gastropoda
    - Family Lepetidae
        - *Lepeta caeca* (Müller)
    - Family Naticidae
        - *Polinices pallida* (Broderip and Sowerby)
    - Family Cymatiidae
        - *Fusitriton oregonensis* (Redfield)
    - Family Muricidae
        - *Trophonopsis lasius* (Dall)
    - Family Thaididae
        - *Nucella lamellosa* (Gmelin)
    - Family Buccinidae
        - *Buccinum plectrum* Stimpson
        - *Colus spitzbergensis* (Reeve)
        - *Colus halli* (Dall)
    - Family Clionidae
        - *Clione limacina* (Phipps)
    - Family Tritonidae
        - *Tritonia exsulans* Bergh
    - Family Dorididae
  - Class Scaphopoda
    - Family Dentaliidae
        - *Dentalium* sp.
  - Class Cephalopoda
    - Family Sepiolidae
        - *Rossia pacifica* Berry
    - Family Gonatidae
        - *Gonatus* sp.
    - Family Octopodidae
        - *Octopus* sp.

- Phylum Arthropoda
  - Class Crustacea
    - Family Balanidae
        - *Balanus crenatus* Pilsbury
        - *Balanus hesperius* Pilsbury
        - *Balanus rostratus* Pilsbury

TABLE VIII
CONTINUED

Phylum Arthropoda (cont'd)
Order Decapoda
Family Pandalidae
Pandalus borealis Kröyer
Pandalus goniurus Stimpson
Pandalus hypsinotus Brandt
Pandalopsis danae Stimpson
Family Hippolytidae
Spironotocaris lamellicornis
Eualus biunguis Rathbun
Eualus macilenta (Kröyer)
Family Crangonidae
Crangon dalli Rathbun
Crangon communis Rathbun
Argis dentata (Rathbun)
Family Paguridae
Pagurus sp.
Pagurus ochotensis Brandt
Pagurus aleuticus (Benedict)
Pagurus capillatus (Benedict)
Elassochirus tenuimanus (Dana)
Labidochirus splendescens (Owen)
Family Majidae
Oregonia gracilis Dana
Hyas lyratus Dana
Chionoecetes bairdi Rathbun
Family Cancridae
Cancer magister Dana
Cancer oregonensis (Dana)

Phylum Sipunculida
unidentified sp.

Phylum Ectoprocta
Order Cyclostomata
Family Heteroporidae
Heteropora spp.

Order Ctenostomata
Family Alcyonidiidae
Alcyonidium spp.

Phylum Brachiopoda
Class Articulata
Family Dallinidae
Laqueus californianus Koch

TABLE VIII
CONTINUED

- **Phylum Echinodermata**
  - Class Asteroidea
    - Family Solasteridae
      - *Crossaster papposus* (Linnaeus)
      - *Solaster dawsoni* Verrill
    - Family Asteriidae
      - *Orthasterias koehleri* (de Loriol)
      - *Pycnopodia helianthoides* (Brandt)
    - Family Goniasteridae
      - *Pseudarchaster parelli* (Düben and Koren)
    - Family Porcellanasteridae
      - *Ctenodiscus crispatus* (Retzius)
    - Family Strongylocentrotidae
      - *Strongylocentrotus droebachiensis* (O. F. Müller)
  - Class Ophiuroidea
    - Family Amphiuridae
      - *Diamphiodia craterodmeta*
    - Family Gorgonocephalidae
      - *Gorgonocephalus caryi* (Lyman)
    - Family Ophiactidae
      - *Ophiopholis aculeata* (Linnaeus)
    - Family Ophiuridae
      - *Ophiura sarsi* Lütken
  - Class Holothuroidea
    - Family Synallactidae
      - *Bathyplotes* sp.

- **Phylum Chordata**
  - Subphylum Urochordata
    - Class Ascidiacea
      - unidentified sp.

respectively, were the sunflower sea star (*Pycnopodia helianthoides*) and the basket star (*Gorgonocephalus caryi*) (Table V). Arthropoda accounted for 45.4% of the total invertebrate biomass (Table III). The families Pandalidae and Majidae made up 38.6% of this biomass (Table IV). The leading species in each of these families, respectively, were the coonstripe shrimp (*Pandalus hypsinotus*), the pink shrimp (*P. borealis*), and the snow crab (*Chionoecetes bairdi*) (Table V). Although 26 species of Mollusca were represented, these species only accounted for 1.84% of the total invertebrate biomass (Tables III-VIII).

Abundance data for the dominant organisms in Zaikof Bay are also listed in Tables III-V.

Feeding

Chionoecetes bairdi from Zaikof Bay fed primarily on bivalves of the family Nuculanidae, other miscellaneous bivalve species, unidentified animal material and sediment (Table VI).

Pycnopodia helianthoides fed on mollusks and a crustacean. Two gastropods (*Mitrella gouldi* and *Lora* spp.) and a clam (*Yoldia* sp.) were the mollusks preyed upon. The crustacean consumed was the crab, *Cancer oregonensis*, (Table VII).

Unidentified animal material, foraminiferans, polychaetes and *Yoldia* spp. were the main organisms consumed by the flathead sole, *Hippoglossoides elassodon* (Appendix Table II). Yellowfin sole, *Limanda aspera*, contained unidentified plant and animal material, and bivalves (*Axinopsida* spp. and representatives of the family Nuculanidae).

Since a limited number of samples were available, some species are not included in Appendix Table II. However, comments on prey items are included here. Dover sole, *Microstomus pacificus*, contained unidentified animal material and polychaetes, including Ampharetidae. Rex sole, *Glyptocephalus zachirus*, contained polychaetes, crustaceans, and fish remains. Arrowtooth flounder, *Atheresthes stomias*, contained unidentified animal material, unidentified Euphausiacea and the euphausiid, *Thysanoessa* *spinifera*. Shortfin eelpout, *Lycodes brevipes*, contained unidentified plant material, bivalves, crustaceans and fish remains. Sediment was also dominant in the stomachs of the above species.

Rocky Bay

Distribution, biomass and abundance

A total of 7 trawl stations was occupied in Rocky Bay, covering a distance of 6.9 km (Table 1). The average epifaunal invertebrate biomass for all stations sampled was 1.24 g/m^2.

Taxonomic analysis of epifaunal invertebrates from Rocky Bay delineated 9 phyla, 16 classes, 48 families, 64 genera and 86 species (Table IX). Echinodermata accounted for 86.9% of the total invertebrate biomass (Table III) with 18 species (Table IX). The families Synallactidae, Ophiuridae and Gorgonocephalidae made up 76.3% of this biomass (Table IV). The leading species, in terms of biomass, in these families were sea cucumbers (*Bathyplotes* spp.), a brittle star (*Ophiura sarsi*), and the basket star (*Gorgonocephalus caryi*) (Table V). Although Arthropoda and Mollusca represented 35 and 24 species, respectively, these phyla only accounted for 5.9 and 3.2% of the total invertebrate biomass (Table III).

Abundance data for the dominant organisms in Rocky Bay are also listed in Tables III-V.

Feeding

Chionoecetes bairdi from Rocky Bay fed primarily on unidentified animal material, sediment, foraminiferans, polychaetes, and ophiuroids (Table VI).

Pycnopodia helianthoides, preyed almost entirely on bivalves, gastropods and crustaceans. A gastropod (*Mitrella gouldi*) and a barnacle (*Balanus crenatus*) were the dominant organisms consumed. Other less important items consumed by *P. helianthoides* were gastropods (*Margarites pupillus*, *Oenopota* spp., *Cylichna alba*), a bivalve (*Clinocardium californiense*) and crab remains (Table VII).

Text continued on page 28

TABLE IX

A LIST OF SPECIES TAKEN BY TRAWL FROM ROCKY BAY, MONTAGUE ISLAND, ALASKA JULY/AUGUST 1978

- Phylum Porifera
    - unidentified sp.

- Phylum Cnidaria
    - Class Hydrozoa
        - unidentified sp.
    - Class Anthozoa
        - Family Nephtyidae
            - *Eunephthya rubiformis* (Pallas)
        - Family Pennatulidae
            - *Ptilosarcus gurneyi* (Gray)
        - Family Actinostolidae
            - *Stomphia coccinea* (O. F. Müller)
        - Family Actiniidae
        - Family Caryophylliidae
            - *Caryophyllia alaskensis* Vaughan

- Phylum Mollusca
    - Class Pelecypoda
        - Family Nuculanidae
            - *Nuculana fossa* Baird
        - Family Pectinidae
            - *Chlamys rubida* Hinds
        - Family Astartidae
            - *Astarte borealis* Schumacher
            - *Astarte alaskensis* Dall
            - *Astarte montagui* (Dillwyn)
            - *Astarte rollandi* Bernard
            - *Astarte esquimalti* Baird
        - Family Cardiidae
            - *Clinocardium ciliatum* (Fabricius)
            - *Clinocardium californiense* (Deshayes)
            - *Serripes groenlandicus* (Bruguière)
    - Class Gastropoda
        - Family Trochidae
            - *Lischkeia cidaris* (Carpenter)
        - Family Naticidae
            - *Natica clausa* (Broderip and Sowerby)
            - *Polinices pallida* (Broderip and Sowerby)
        - Family Cymatiidae
            - *Fusitriton oregonensis* (Redfield)
        - Family Muricidae
            - *Trophonopsis* spp.
        - Family Buccinidae
            - *Buccinum plectrum* Stimpson
            - *Colus halli* (Dall)

TABLE IX

CONTINUED

Phylum Mollusca
- **Class Gastropoda (cont'd)**
  - **Family Neptuneidae**
    - *Neptunea lyrata* (Gmelin)
  - **Family Columbellidae**
    - *Amphissa columbiana* Dall
  - **Family Volutomitridae**
    - *Volutomitra alaskana* Dall
  - **Family Turridae**
    - *Leucosyrinx circinata* (Dall)
  - **Family Dorididae**
  - **Family Tritoniidae**
    - *Tochuina tetraquatra* (Pallas)
- **Class Cephalopoda**
  - **Family Sepiolidae**
    - *Rossia pacifica* Berry

Phylum Arthropoda
- **Class Crustacea**
  - **Family Balanidae**
    - *Balanus crenatus* Pilsbury
    - *Balanus balanus* Pilsbury
    - *Balanus hesperius* Pilsbury
    - *Balanus rostratus* Pilsbury
- **Order Decapoda**
  - **Family Pandalidae**
    - *Pandalus borealis* Kröyer
    - *Pandalus montagui tridens* Rathbun
    - *Pandalus platyceros* Brandt
    - *Pandalus hypsinotus* Brandt
  - **Family Hippolytidae**
    - *Spirontocaris* spp.
    - *Spirontocaris lamellicornis* (Dana)
    - *Lebbeus groenlandica* (Fabricius)
    - *Lebbeus polaris* Sabine
    - *Eualus* spp.
    - *Eualus biunguis* Rathbun
    - *Eualus pusiola* (Kröyer)
  - **Family Crangonidae**
    - *Crangon dalli* Rathbun
    - *Crangon communis* Rathbun
    - *Argis dentata* (Rathbun)
    - *Paracrangon echinata* Dana

TABLE IX
CONTINUED

- **Phylum Arthropoda (cont'd)**
    - **Family Paguridae**
        - *Pagurus* sp.
        - *Pagurus ochotensis* Brandt
        - *Pagurus aleuticus* (Benedict)
        - *Pagurus capillatus* (Benedict)
        - *Pagurus kennerlyi* (Stimpson)
        - *Elassochirus tenuimanus* (Dana)
        - *Elassochirus cavimanus* (Miers)
        - *Labidochirus splendescens* (Owen)
    - **Family Galatheidae**
        - *Munida quadrispina* Benedict
    - **Family Majidae**
        - *Oregonia gracilis* Dana
        - *Hyas lyratus* Dana
        - *Chionoecetes bairdi* Rathbun
        - *Pugettia gracilis* (Dana)
    - **Family Cancridae**
        - *Cancer magister* Dana
    - **Family Atelecyclidae**
        - *Telmessus cheiragonus* (Tilesius)

- **Phylum Sipunculida**
    - *Golfingia margaritacea*

- **Phylum Ectoprocta**
    - **Order Cyclostomata**
        - **Family Heteroporidae**
            - *Heteropora pacifica*

- **Phylum Brachiopoda**
    - **Class Articulata**
        - **Family Dallinidae**
            - *Terebratalia transversa* (Sowerby)
            - *Laqueus californianus* Koch

- **Phylum Echinodermata**
    - **Class Asteroidea**
        - **Family Goniasteridae**
            - *Mediaster aequalis* Stimpson
        - **Family Porcellanasteridae**
            - *Ctenodiscus crispatus* (Retzius)
        - **Family Pterasteridae**
            - *Pteraster tesselatus* Fisher

TABLE IX

CONTINUED

Phylum Echinodermata
  Class Asteriidae (cont'd)
    Family Solasteridae
      Crossaster papposus (Linnaeus)
      Solaster spp.
      Solaster endeca (Linnaeus)
    Family Asteridae
      Lethasterias nanimensis (Verrill)
      Orthasterias koehleri (de Loriol)
      Stylastasterias forreri (de Loriol)
      Pycnopodia helianthoides (Brandt)
    Family Pedicellasteridae
      Pedicellaster magister Djakonov
    Family Strongylocentrotidae
      Strongylocentrotus droebachiensis (O. F. Müller)

  Class Ophiuroidea
    Family Gorgonocephalidae
      Gorgonocephalus caryi (Lyman)
    Family Ophiuridae
      Ophiura sarsi Lütken

  Class Holothuroidea
    Family Stichopodidae
      Parastichopus californicus (Stimpson)
    Family Synallactidae
      Bathyplotes sp.
    Family Psolidae
      Psolus chitinoides (Clark)

  Class Crinoidea
      Heliometra glacialis maxima Clark

Phylum Chordata
  Class Ascidiacea
      unidentified sp.

Polychaetes, bivalves, crustaceans including Gnathiidae, and fish remains were the main organisms consumed by the searcher, *Bathymaster signatus* (Appendix Table II).

Since a limited number of samples were available, some species are not included in Appendix Table II. However, comments on prey items are included here. Walleye pollock, *Theragra chalcogramma*, contained unidentified animal material and crustaceans. Flathead sole, *Hippoglossoides elassodon*, contained unidentified animal material, crustaceans, and echinoderms. Rex sole, *Glyptocephalus zachirus*, contained unidentified animal material, Nephtyidae and crustaceans. Dover sole, *Microstomus pacificus*, contained polychaetes and crustaceans. Arrowtooth flounder, *Atheresthes stomias*, contained unidentified animal material and fish. Sediment was also dominant in the stomachs of the above species.

DISCUSSION

Station Coverage

The trawl program described in this report represents the first intensive analysis of the epifaunal invertebrates of Port Etches, Zaikof Bay, and Rocky Bay. Thirteen stations were occupied in Port Etches with 8 and 7 stations, respectively, occupied in Zaikof Bay and Rocky Bay. The average distance fished at each station was 0.99 km. Bottom topography in Zaikof Bay and Rocky Bay made selection of trawlable areas difficult.

Biomass

The values for epifaunal standing stocks reported in the present study are somewhat less than standing stock estimates presented in OCSEAP benthic trawl studies elsewhere, i.e., see Jewett and Feder, 1976; Feder *et al.*, in press. The average biomass for all epifaunal invertebrates in the northeast Gulf of Alaska (NEGOA) was 2.6 g/m^2 (Jewett and Feder, 1976). The biomass determined for epifaunal invertebrates in the southeast Bering Sea was 3.3 g/m^2 in 1975 and 5.0 g/m^2 in 1976 (Feder and Jewett, in press). The epifaunal biomass for Alitak and Ugak Bays was 4.74 g/m^2 (Feder and Jewett, 1977). The average epifaunal biomass for Port Etches, Zaikof Bay and Rocky Bay, for the present sampling period was 0.82 g/m^2 (Table I).

The low average biomass for Port Etches, Zaikof Bay and Rocky Bay may be attributed to the sampling gear used, the try net. Large epifaunal invertebrates such as crabs may be able to avoid this small net, unlike the larger otter trawls.

Russian benthic investigations (Neiman, 1963), provide biomass estimates based on grab samples for infauna and small epifauna from the southeast Bering Sea with the lowest value reported as 55 g/m^2. Use of a commercial-size trawl results in the loss of infaunal and small epifaunal organisms that are an important part of the benthic biomass. Therefore, the total benthic biomass value is probably best expressed by combining both grab and trawl values. Combined infaunal and epifaunal surveys should be a part of all future benthic invertebrate investigations (infaunal samples are available from these three bays; analysis of these samples is in progress).

Species Composition and Diversity

Examination of the species composition of Port Etches, Zaikof Bay and Rocky Bay revealed crustaceans, molluscs and echinoderms to be the major epifaunal invertebrates present.

In general, the epifaunal species richness for Port Etches, Zaikof Bay and Rocky Bay in Prince William Sound was similar to that reported for NEGOA (Jewett and Feder, 1976) and four bays of Kodiak and Afognak Islands in the Gulf of Alaska, i.e., Alitak and Ugak Bays (Feder and Jewett, 1977) and Izhut and Kiliuda Bays (Feder and Jewett, in press). The major epifaunal differences between NEGOA and the Prince William Sound Bays-Kodiak Bay fauna were the low numbers of species of annelid and echinoderms found in the bays. The survey in NEGOA revealed 30 species of Annelida and 36 species of Echinodermata; however, these phyla in Alitak and Ugak Bays comprised only 5 and 12 species, in Port Etches 1 and 4 species, in Zaikof Bay 4 and 12 species, and in Rocky Bay 0 and 17 species, respectively.

The Solasteridae and the Asteriidae were the most diverse echinoderm families collected with 8 species represented. Pandalidae, Hippolytidae, Crangonidae, and Paguridae were the most diverse crustacean families collected with 30 species represented. Astartidae, Cardiidae, and Buccinidae were the most diverse molluscan families collected, with 10 species represented.

Food Habits

The main species examined for stomach contents were the snow crab (*Chionoecetes bairdi*) and the sunflower sea star (*Pycnopodia helianthoides*).

Inference from the present study, as well as past snow crab food studies (Yasuda, 1967; Feder and Jewett, 1977; 1980, in press; Paul *et al.*, 1979; Feder and Matheke, 1980) involving prey species, suggests that items used for food by snow crab are area specific. Most of the important items consumed by snow crab in Port Etches, Zaikof Bay and Rocky Bay, (i.e., gastropods, bivalves, snow crab, sediment) differed somewhat from those used by this species in Cook Inlet and Kodiak Island (Feder and Jewett, 1977; Feder and Paul, 1980). Paul *et al.* (1979) examined 715 snow crabs in Cook Inlet, and found the main items, in order of decreasing percent frequency of occurrence in stomachs, were bivalves, hermit crabs (*Pagurus* spp.), barnacles (*Balanus* spp.), and sediment. The only similar food items used by snow crab in the present study were clams and sediment. Snow crab stomachs examined in Port Valdez primarily contained sediment (Feder and Matheke, 1980). The role of sediment in crab feeding is not known. However, Moriarty (1977) reported on the occurrence of sediment in the food contents of five species of penaeid shrimps. The nutritional benefit of sediment for these shrimps appeared to be derived from the film of organic carbon, including bacteria, on sand grains. Yasuda (1967) found benthic diatoms to be abundant in *Chionoecetes opilio elongatus* stomachs in the Bering Sea, but postulated that diatoms were taken inadvertently with food and sediment.

Data from the present study, as well as other sunflower sea star investigations (e.g., Mauzey *et al.*, 1968; Paul and Feder, 1975; Jewett and Feder, 1976; Feder and Jewett, in press) suggest that food used by *Pycnopodia helianthoides* is similar in different geographic locations. The important food items (i.e., gastropods and bivalves) consumed by sunflower sea stars in Port Etches, Zaikof and Rocky Bays confirm the food items used by this species in four other northeastern bays of Prince William Sound (Paul and Feder, 1975), Izhut and Kiliuda Bays of Kodiak Island (Jewett and Feder, in press), and NEGOA (Jewett and Feder, 1976; Feder *et al.*, in press). Paul and Feder (1975) reported intertidal and shallow subtidal *P. helianthoides* from Prince William Sound feeding primarily on small bivalve mollusks. However, the sea star is also capable of excavating for large clams (Mauzey *et al.*, 1968; Paul and Feder, 1975; Feder and Jewett, in press) examined sunflower sea stars from Kodiak Island and found the main items, in order of decreasing percent frequency of occurrence, were snails (*Oenopota* spp. and *Solariella* spp.) and bivalves (*Nuculana fossa*, *Psephidia lordi* and *Spisula polynyma*). Feder *et al.* (in press) examined sunflower sea stars in NEGOA, and found *Ophiura sarsi*, Cardiidae, Naticidae to be the dominant food items.

One of the known predator and food competitors of *P. helianthoides* is the king crab, *Paralithodes camtschatica*. Many *P. helianthoides* observed by SCUBA diving near Kodiak Island were tightly squeezed into rock crevices when king crab were in the vicinity. This behavior may represent an avoidance response by the sea star (Feder and Jewett, in press).

CONCLUSION

Benthic trawling operations in Port Etches resulted in the collection of six invertebrate phyla and 39 species; Zaikof Bay and Rocky Bay produced 11 and 78, and 9 and 86 phyla and species, respectively. Echinoderms dominated the biomass in all three bays. The sea star, *Pycnopodia helianthoides*, was dominant in Port Etches and Zaikof Bay, and the basket star, *Gorgonocephalus caryi*, was dominant in Rocky Bay as well as Zaikof Bay. Species dominated each bay in the following manner: Port Etches — Arthropoda (22 species), Mollusca (8) and Echinodermata (4); Zaikof Bay — Mollusca (27), Arthropoda (24) and Echinodermata (12); and Rocky Bay — Arthropoda (35), Mollusca (24) and Echinodermata (18).

Since echinoderms made up the bulk of the epifaunal invertebrate biomass in the study areas, their biological importance cannot be overlooked. It is suggested that these organisms do not represent relatively immobile carbon reservoirs as has been often suggested. Instead, they contribute pulses of high energy organic material, as gametes, into adjacent waters during their spawning periods. It is possible that the gametes shed by the large populations of echinoderms in the study areas represent important components generally overlooked in calculations of secondary productivity (Feder and Paul, unpub.).

Feeding data on invertebrates and fishes in the present study, in addition to feeding data compiled in previous OCSEAP studies, enhance our understanding of benthic trophic relationships for the Gulf of Alaska shelf.

There is now a satisfactory knowledge, on a station basis (for the months sampled), of the distribution, abundance and biomass of the major epifaunal invertebrates in the three bays studied. Additional seasonal data are essential. It is only when continuing information is available that a reasonable assessment of the effect of an oil spill on the benthic biota of these areas can be accomplished.

Availability of many readily identifiable, biologically well understood organisms is a preliminary to the development of monitoring programs. Sizeable biomasses of taxonomically well-known echinoderms, crustaceans, and molluscs were typical of most of our stations, and many species of these phyla were sufficiently abundant to represent organisms potentially useful as monitoring tools. The present investigation has clarified several aspects of the biology of some of these organisms, and should aid in the development of future monitoring programs for the Prince William Sound areas.

REFERENCES

Arctic Environmental Information and Data Center. 1975. Kadyak - a background for living. Univ. Alaska, AEIDC Publ. No. B-75, Sea Grant Publ. No. 75-9. 326 pp.

Anonymous. 1964. Catch records of a trawl survey conducted by the International Pacific Halibut Commission between Unimak Pass and Spencer, Alaska from May 1961 to April 1963. Report, I.P.H.C. 36:524.

Bakus, G. J. and D. W. Chamberlain. 1975. An Oceanographic and Marine Biological Study in the Gulf of Alaska. Report submitted to Atlantic Richfield Co. 57 pp.

Boesch, D. F., C. H. Hershner and J. H. Milgram. 1974. *Oil Spills and the Marine Environment*. Ballinger Publishing Co., Cambridge, Mass. 114 pp.

Donaldson, W. 1977. Project No. 5-35-R Commercial Fisheries Research and Development Act. Kodiak, Alaska tanner crab (*Chionoecetes bairdi*) research. July 1, 1973 to June 30, 1976. Report to NOAA, NMFS, Washington, D.C. pp. 140.

Feder, H. M. and S. C. Jewett. 1977. The distribution, abundance, biomass and diversity of the epifauna of two bays (Alitak and Ugak) of Kodiak Island, Alaska. Inst. Mar. Sci. Rept. R77-3, Univ. Alaska, Fairbanks. 74 pp.

Feder, H. M. and S. C. Jewett. 1980. A survey of the invertebrates of the southeastern Bering Sea with notes on the feeding biology of selected species. Inst. Mar. Sci. Rept. R78-5, Univ. Alaska, Fairbanks. 105 pp.

Feder, H. M. and S. C. Jewett. In press. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of the Kodiak Continental Shelf. Inst. Mar. Sci. Rept. R81-1, Univ. Alaska, Fairbanks.

Feder, H. M. and G. E. Matheke. 1979. Distribution, abundance, community structure, and trophic relationships of the benthic infauna of the northern Gulf of Alaska. Final Rept. to NOAA, R.U. #5, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 247 pp.

Feder, H. M. and G. E. Matheke. 1980. Subtidal Benthos. Chapter 9. *In* J. M. Colonell (ed.), *Environmental Studies of Port Valdez, Alaska: 1967-1979*. Inst. Mar. Sci. Occas. Pub. No 5, Univ. Alaska, Fairbanks. 382 pp.

Feder, H. M. and G. Mueller. 1975. Environmental assessment of the northeast Gulf of Alaska: Benthic Biology. First Year Final Report to NOAA. Inst. Mar. Sci. 200 pp.

Feder, H. M. and A. J. Paul. 1978. Biological cruises of the R/V *Acona* in Prince William Sound, Alaska from 1970-1973. Inst. Mar. Sci. Rept. R77-4 (Sea Grant Rept. 76-6), Univ. Alaska, Fairbanks. 76 pp.

Feder, H. M. and A. J. Paul. 1980. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of Cook Inlet. Final Rept. to NOAA, R.U. #5, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 609 pp.

Feder, H. M., G. T. Mueller, M. H. Dick and D. B. Hawkins. 1973. Preliminary Benthos Survey, pp. 305-386. *In* D. W. Hood, W. E. Shields and E. J. Kelley (eds.), *Environmental Studies of Port Valdes.* Inst. Mar. Sci. Occas. Publ. No. 3, Univ. Alaska, Fairbanks. 495 pp.

Feder, H. M., K. Haflinger, M. Hoberg and J. McDonald. 1980. The infaunal invertebrates of the southeastern Bering Sea. Final Rept. to NOAA, R.U. #5, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 399 pp.

Feder, H. M., S. C. Jewett, S. McGee. In press. Distribution, abundance, community structure and trophic relationships of the benthos of the northeast Gulf of Alaska extending from Icy Bay to Cape Fairweather. Final Rept. to NOAA R.U. #5, Inst. Mar. Sci., Univ. Alaska, Fairbanks.

Hitz, C. R. and W. F. Rathjen. 1965. Bottom trawling surveys of the northeastern Gulf of Alaska. *Comm. Fish. Review* 27(9):1-15.

Hughes, S. E. 1974. Groundfish and crab resources in the Gulf of Alaska - based on International Pacific Halibut Commission trawl surveys, May 1961 - March 1963. U.S. Dept. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Data Rept.

Jewett, S. C. 1977. Food of the Pacific cod, *Gadus macrocephalus* Tilesius, near Kodiak Island, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 23 pp.

Jewett, S. C. and H. M. Feder. 1976. Distribution and abundance of some epibenthic invertebrates of the northeast Gulf of Alaska, with notes on the feeding biology of selected species. Inst. Mar. Sci. Rept. R76-8, Univ. Alaska, Fairbanks. 61 pp.

Jewett, S. C. and G. C. Powell. 1979. Summer food of the sculpins *Myoxocephalus* spp. and *Hemilepidotus jordani*, near Kodiak Island, Alaska. *Mar. Sci. Comm.* 5(4,5):315-331.

Karinen, J. F. and S. D. Rice. 1974. Effects of Prudhoe Bay crude oil on molting Tanner crabs, *Chionoecetes bairdi*. *Mar. Fish. Rev.* (36(7): 31-37.

Kineman, J. J., R. Elmgren and S. Hansson. 1980. The Tsesis Oil Spill. U.S. Dept. of Commerce. NOAA Outer Continental Shelf Environmental Assessment Program. 296 pp.

Lewis, J. R. 1970. Problems and approaches to base-line studies in coastal communities. FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing. FIR:MP 70/E-22. 7 pp.

Mauzey, K. P., C. Birkeland and P. K. Dayton. 1968. Feeding behavior of asteroids and escape responses of their prey in the Puget Sound region. *Ecology* 49:603-619.

Moriarty, D. J. W. 1977. Quantification of carbon, nitrogen and bacterial biomass in the food of some Penaeid prawns. *Aust. J. Freshwater Res.* 28:113-118.

Mueller, G. 1975. A preliminary taxon list and code for ADP processing. Sea Grant Proj. A/77-02. 159 pp.

Neiman, A. A. 1963. Quantitative distribution of benthos and food supply of demersal fish in the eastern part of the Bering Sea. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 50:145-205. (Transl. from Russian by Israel Prog. Sci. Transl., Jerusalem, as Soviet Fish. Inv. Northeast Pacific. Part I. pp. 143-217).

Nelson-Smith, A. 1973. *Oil Pollution and Marine Ecology*. Paul Elek (Scientific Books) Ltd., London. 260 pp.

Olson, T. A. and F. J. Burgess (eds). 1967. *Pollution and Marine Ecology*. Interscience, New York. 364 pp.

Paul, A. J. and H. M. Feder. 1975. The food of the sea star *Pycnopodia helianthoides* (Brandt) in Prince William Sound, Alaska. *Ophelia* 14:15-22.

Paul, A. J., H. M. Feder and S. C. Jewett. 1979. Food of the snow crab *Chionoecetes bairdi* Rathbun 1924, from Cook Inlet, Alaska. *Crustaceana* 5:62-68.

Pearson, T. H. 1971. The benthic ecology of Loch Linnhe and Lock Eil, a sea loch system on the west coast of Scotland. III. The effect on the benthic fauna of the introduction of pulp mill effluent. *J. Exp. Mar. Biol. Ecol.* 6:211-233.

Pearson, T. H. 1972. The effect of industrial effluent from pulp and paper mills on the marine benthic environment. *Proc. Roy. Soc. Long. B.* 130P469-485.

Pearson, T. H. 1975. The benthic ecology of Loch Linnhe and Loch Eil, a sea loch system on the west coast of Scotland. IV. Changes in the benthic fauna attributable to organic enrichment. *J. Exp. Mar. Biol. Ecol.* 20:1-41.

Pearson, T. H. 1980. Marine pollution effects of pulp and paper industry wastes. *Helgoländer Meeresunters* 33:340-365.

Powell, G. C., R. Kaiser and R. Peterson. 1974. King crab study. Alaska Department of Fish and Game Completion Report. Project No. 5-30-R. 69 pp.

Rhoads, D. C. 1974. Organism-sediment relations on the muddy sea floor. *Oceanogr. Mar. Biol. Ann. Rev.* 12:263-300.

Ronholt, L. L., H. H. Shippen and E. S. Brown. 1976. An assessment of the demersal fish and invertebrate resources of the northeastern Gulf of Alaska, Yakutat Bay to Cape Cleare, May-August 1975. Ann. Rept. U.S. Dept. Commer., Natl. Oceanic Atmos. Admin., Nat. Mar. Fish. Serv. 184 pp.

Rosenberg, D. H. (ed.). 1972. A review of the oceanography and renewable resources of the northern Gulf of Alaska. Inst. Mar. Sci. Rept. R72-23, Sea Grant Rept. 73-3. 690 pp.

Rosenberg, R. 1973. Succession in benthic macrofauna in a Swedish fjord subsequent to the closure of a sulphite pulp mill. *Oikos* 24:244-258.

Schaefers, E. A., K. S. Smith, M. R. Greenwood. 1955. Bottomfish and shellfish explorations in Prince William Sound area, Alaska, 1954. *Comm. Fish. Rev.* 17(4):6-28 (also Sep. No. 398).

Smith, J. E. (ed.). 1968. *Torrey Canyon Pollution and Marine Life.* Cambridge Univ. Press, Cambridge. 196 pp.

Smith, R., A. Paulson and J. Rose. 1976. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. Ann. Rept. to NOAA R.U. #284, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 38 pp.

Straughan, D. 1971. *Biological and Oceanographic Survey of the Santa Barbara Channel Oil Spill 1969-1970.* Allan Hancock Foundation, Univ. Southern California, Los Angeles. 425 pp.

Yasuda, T. 1967. Feeding habits of the Zuwaigani, *Chionoecetes opilio elongatus*, in Wakasa Bay. I. Specific composition of the stomach contents. *Bull. Jap. Soc. Sci. Fish* 33(4):315-319. (Transl. from Jap.-Fish. Res. Bd. Can. Transl. Ser. No. 1111).

Zenkevitch, L. A. 1963. *Biology of the Seas of the USSR.* George Allen and Unwin., Ltd., London. 955 pp.

APPENDIX TABLE I

BENTHIC TRAWL STATIONS OCCUPIED IN THREE BAYS IN PRINCE WILLIAM SOUND, 1978

Area	Station	Coordinates	Depth (m)
Rocky Bay			
	1	60°23'7 147°04'0	62
	2	60°23'5 147°02'0	57
	3	60°22'4 147°00'0	70
	4	60°21'4 146°58'0	85
	5	60°21'9 147°02'0	66
	6	60°20'9 147°06'0	54
	7	60°21'5 147°04'0	75
Zaikof Bay			
	8	60°16'5 147°05'0	39
	9	60°17'0 147°04'0	43
	10	60°17'6 147°03'0	42
	11	60°18'1 147°01'0	52
	12	60°18'6 147°01'0	64
	13	60°19'0 147°00'0	58
	14	60°20'0 146°58'0	74
	15	60°19'0 146°58'0	61
Port Etches			
	16	60°20'0 146°42'0	66
	17	60°18'4 146°40'7	98
	18	60°18'5 146°38'7	64
	19	60°19'1 146°36'9	75
	20	60°19'4 146°37'4	78
	21	60°19'6 146°38'0	75
	22	60°19'6 146°35'4	66
	23	60°19'9 146°35'9	65
	24	60°20'2 146°36'3	44
	25	60°20'3 146°35'3	42
	26	60°20'2 146°34'0	34
	27	60°20'8 146°34'4	47
	28	60°20'7 146°33'3	27

APPENDIX TABLE II

PERCENT FREQUENCY OF OCCURRENCE OF FOOD ITEMS CONSUMED BY SEVERAL FISH SPECIES
IN PORT ETCHES, ZAIKOF BAY AND ROCKY BAY, ALASKA. JULY/AUGUST 1978

	Glyptocephalus zachirus	*Hippoglossoides elassodon*		*Lepidopsetta bilineata*	*Limanda aspera*		*Lycodes brevipes*	*Bathymaster signatus*
	Port Etches (N=12)	Port Etches (N=22)	Zaikof Bay (N=12)	Port Etches (N=11)	Port Etches (N=18)	Zaikof Bay (N=9)	Port Etches (N=13)	Rocky Bay (N=22)
Unidentified Plant Material	92	10	-	9	6	89	15	5
Algae frag.	8	-	-	-	-	-	15	-
Coscinodiscus sp.	-	-	8	-	-	-	-	-
Rhodophyta	-	-		9	-	-	-	-
Foraminifera	8	-	42	-	-	22	23	-
Pyrgo sp.	-	-	-	-	-	-	31	-
Polychaeta	58	5	50	45	22	33	69	23
Polynoidae	42	-	-	-	-	-	8	9
Phyllodocidae	17	-	-	-	-	-	-	-
Nereidae	-	-	-	-	-	11	-	-
Nephtyidae	83	-	-	9	-	-	15	9
Nephtys sp.	-	10	8	-	-	11	-	-
Exogone sp.	-	-	-	9	-	-	-	-
Glyceridae	-	-	-	27	-	-	-	-
Glycinde sp.	-	-	-	9	-	-	-	-
Lumbrineridae	83	-	-	9	-	-	-	-
Eunicidae	-	-	-	-	-	-	-	27
Spionidae	17	-	-	27	6	11	8	5
Maldanidae	-	-	-	-	-	-	-	5
Prionospio malmgreni	-	-	-	9	-	-	-	-
Magelona pacifica	-	-	-	9	-	-	-	-
Scalibregmidae	-	-	-	9	-	-	-	-
Owenia fusiformis	-	-	-	9	-	-	-	-
Ammotrypane aulogaster	8	-	-	-	-	-	-	-
Sternaspis scutata	8	-	-	-	-	-	-	-
Terebellidae	-	-	-	9	6	-	-	-
Terebellides stroemi	-	-	-	9	-	-	-	-
Sabellidae	17	-	-	27	-	-	23	-
Serpulidae	-	-	-	-	-	-	8	-
Bivalvia	17	5	-	-	28	33	15	5
Nucula tenuis	33	5	8	9	6	44	92	-
Nuculana sp.	-	-	-	9	11	67	-	-
Nuculana fossa	-	24	-	-	-	-	92	-
Yoldia sp.	25	14	42	-	6	89	46	-
Musculus sp.	-	-	-	9	-	-	8	-
Axinopsida sp.	33	-	-	-	-	56	-	-
Axinopsida serricata	-	-	-	-	-	-	38	-
Axinopsida viridis	-	-	-	-	-	-	46	-
Mysella sp.	-	-	-	-	-	22	-	-
Serripes sp.	-	-	-	-	-	11	-	-
Psephidia lordi	-	-	-	-	-	22	15	-
Macoma sp.	-	-	-	-	6	11	-	-
Tellina nuculoides	-	-	-	27	6	-	-	-
Pandora sp.	-	-	-	-	-	22	8	-
Lyonsia sp.	-	10	-	36	-	11	-	-
Dentalium dalli	-	-	-	-	-	11	-	-
Gastropoda	-	-	-	-	11	-	8	5
Alvinia sp.	-	-	-	-	-	11	15	-
Mitrella sp.	-	-	8	-	-	-	-	-
Olivella baetica	-	-	-	9	-	-	-	-
Cingula sp.	-	-	-	-	-	11	8	-
Barleeia sp.	-	-	-	-	-	-	8	-
Odostomia sp.	-	-	-	-	-	11	8	-

APPENDIX TABLE II

CONTINUED

	Glyptocephalus zachirus	*Hippoglossoides elassodon*		*Lepidopsetta bilineata*	*Limanda aspera*		*Lycodes brevipes*	*Bathymaster signatus*
	Port Etches (N=12)	Port Etches (N=22)	Zaikof Bay (N=12)	Port Etches (N=11)	Port Etches (N=18)	Zaikof Bay (N=9)	Port Etches (N=13)	Rocky Bay (N=22)
Cylichna sp.	-	-	-	-	6	11	-	-
Retusa sp.	8	-	-	-	-	-	-	-
Diaphana sp.	-	-	-	-	-	-	8	-
Crustacea	58	-	8	9	22	-	23	5
Ostracoda	-	-	-	-	-	-	8	-
Calanoidea	8	-	17	-	-	11	-	-
Harpacticoidea	25	-	-	-	6	-	23	-
Balanus sp.	-	5	-	-	-	-	-	-
Cumacea	17	5	8	-	-	33	31	-
Leucon sp.	8	-	-	-	-	11	-	-
Nymphon sp.	-	-	-	-	-	-	-	5
Eudorella sp.	67	-	-	-	-	11	-	18
Eudorella emarginata	-	-	-	-	-	-	31	-
Eudorellopsis sp.	8	-	-	-	-	-	-	-
Diastylis sp.	25	-	-	-	-	-	8	-
Tanaidacea	25	-	-	-	-	-	-	-
Isopoda	-	10	-	-	-	-	-	-
Gnathiidae	-	-	-	-	-	-	-	68
Amphipoda	67	33	33	73	44	44	31	45
Gammaridea	-	-	8	-	-	-	-	-
Vibilia sp.	-	-	-	-	6	-	-	-
Parathemisto sp.	-	-	-	-	-	-	-	36
Ampeliscidae	25	5	8	-	-	-	-	-
Euphausiidae	-	10	17	9	-	-	-	14
Thysanoessa spinifera	-	-	33	-	-	-	-	-
Decapoda	-	-	-	-	-	11	-	-
Shrimp frag.	-	24	17	-	-	-	8	-
Hippolytidae	-	5	-	-	-	-	-	-
Pandalidae	8	33	8	-	17	-	-	-
Pandalus borealis	-	10	8	-	-	-	-	-
Pandalus goniurus	-	5	-	-	-	-	-	-
Crangonidae	-	-	-	-	17	-	-	-
Crangon sp.	-	14	-	-	-	-	-	-
Crab frag.	8	-	-	-	6	-	-	5
Crab zoea	-	-	-	9	-	-	-	-
Pagurus sp.	-	10	17	-	6	-	-	9
Pagurus ochotensis	-	10	-	-	-	-	-	-
Pagurus beringanus	-	-	-	-	-	-	8	-
Pinnixa sp.	8	-	-	-	6	-	-	-
Pinnixa occidentalis	-	10	-	-	-	-	-	-
Chionoecetes bairdi	-	24	8	-	22	-	-	5
Insecta	-	-	-	-	-	11	-	-
Hemiptera (aphid)	-	-	-	-	-	-	-	5
Golfingia margaritacea	-	-	-	9	-	-	-	-
Echinodermata	-	-	-	-	6	11	-	-
Asteroidea	-	-	8	-	-	-	-	-
Ophiuroidea	-	-	8	9	-	-	8	-
Holothuroidea	-	-	-	-	-	-	8	-
Urochordata	-	-	-	9	6	-	-	-
Chaetognatha	-	-	-	-	-	-	-	5
Pisces (Fish) remains	58	24	33	18	22	33	15	55
Unidentified Animal Material	92	67	75	91	94	100	92	95
Sediment	83	48	75	82	67	89	69	41

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OCSEAP FINAL REPORT

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DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE AND TROPHIC RELATIONSHIPS OF THE NEARSHORE BENTHOS OF COOK INLET

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Figure VI.E. 1 Larval period for Cook Inlet curstaceans. Data from Alaska Department of Fish and Game 344

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objectives of this study included an inventory and census of dominant benthic species and their critical habitats. Information on important species in the food webs supporting the commercially harvested benthic crustaceans and their methods of feeding was also collected. Feeding studies of the zoeae of three species of crab and shrimp were initiated. Growth histories were determined for several species of long lived, sedentary, small clams.

Epifaunal invertebrate biomass estimations at the ten most productive stations of the 41 examined ranged from 14 to 3 g/m^2. Five of the ten most productive stations occurred in Kachemak Bay; one in outer Kamishak Bay, three near the mouth of the Inlet between Shaw Island and the Barren Islands, and one in the central area of the Inlet.

Kachemak Bay, Kamishak Bay and the area between Shaw Island and the Barren Islands were found to be important habitats for snow and king crabs. Few adults of these species were captured in the northern half of the oil-lease tract selection area. In the southern section of the tract selection area approximately along 59° of latitude, adult snow crabs were occasionally abundant. The only major nursery area for snow crabs found in Cook Inlet was along this same latitude, extending approximately 30 km northward into the tract selection area. Young snow crabs were also located throughout Kamishak Bay. The only known nursery area observed for king crabs, was found along the north shore of outer Kachemak Bay. Dungeness crab were restricted to Kachemak Bay. With the exception of large numbers of humpy shrimp in northern Kamishak Bay and Chinitna Bay, inner Kachemak Bay is the area where most of the pandalid shrimps were captured. Outer Kachemak Bay is also an important habitat of pandalids.

The large species of crab (snow, Dungeness and king crab) in Cook Inlet prey primarily on bivalves, barnacles, hermit crabs and crangonid shrimps. These prey organisms feed either by filtering particulate organic material, both that settling from above and resuspended from the sediment, or utilize a combination of sediment sorting and predation on other detritivores. The pandalid shrimps feed primarily on polychaetes and bivalves, and ingest large amounts of sediment and detritus. Post-larval king crab feed mainly on small crustaceans, and also ingest large amounts of sediment and detritus.

The zoeae of king crab, snow crab and pink shrimp require zooplankton prey concentrations on the order of 40 to 80 organisms per liter in order to feed successfully in the laboratory. Prey concentration was observed to be more important in determining later feeding ability of king crab zoeae than water temperature within the range of 2° to 6°C. King crab zoeae can only survive starvation for 3.5 days before losing their ability to capture zooplankton prey.

Since subtidal bivalves, like other infaunal organisms in lower Cook Inlet, have nonrandom distributions, precise population monitoring of these organisms is probably not feasible. Thus, growth rates of bivalves were examined as a more useful parameter for monitoring environmental changes within the Inlet. Size and age data were collected for six bivalve species in the Inlet. Growth rates were found to be relatively similar throughout lower Cook Inlet. Monitoring growth rates for environmental changes appear to be feasible.

Oil contamination of the benthic environment in Kachemak Bay, Kamishak Bay or the large area near the mouth of the Inlet between Shaw Island and the Barren Islands could negatively effect the populations of crab and shrimp. In addition to the dangers to benthic organisms resulting from the toxic properties of oil, hydrocarbon fractions associated with subtidal sediments or settled drilling muds could be inadvertently ingested and assimilated by clams, pandalid and crangonid shrimps, hermit crabs, and post-larval king crabs, all of which feed by sediment sorting. Large crab species as well as same fishes could then be affected by feeding on these contaminated prey organisms.

The zoeae of king crab, snow crab and pink shrimp appear to require zooplankton prey concentrations on the order of 40 per liter. This is a relatively high density and it is possible that a naturally limiting food supply exists which regulates recruitment success of these larvae. Zoeae are extremely sensitive to low levels of oil pollution in the laboratory, and oil pollution would be an added stress to food limited larvae. Thus, oil pollution could result in a reduction in the stocks of these crustaceans. However, lack of information on the effect of oil pollution on benthic species of Cook Inlet currently precludes quantitative estimations of the extent or type of damage that oil contamination could cause.

II. INTRODUCTION

GENERAL NATURE AND SCOPE OF STUDY

The operations connected with oil exploration, production, and transportation in Cook Inlet present a wide spectrum of potential dangers to marine benthic organisms. Initially the benthic biological program in Cook Inlet emphasized development of an inventory of species as part of the examination of biological, physical and chemical components of those portions of the shelf slated for oil exploration and drilling activity. Very little information on the non-commercial benthic fauna of Cook Inlet was available before this study. Experience in pollution-prone areas of England (Smith, 1968), Scotland (Pearson, 1972, 1975; Pearson and Rosenberg, 1978) and California (Straughan, 1971) suggests that after the completion of an initial study, selected stations should be examined regularly on a several-year basis to determine changes in species content, diversity, abundance and biomass. The data collected by trawls, grabs and dredges on the eight available OCSEAP cruises in lower Cook Inlet (April 1976-August 1978) provide a species inventory for the area. However the data collected are insufficient to generate the data necessary for the development of a population monitoring program. Following reduced OCSEAP funding in 1977-78 the emphasis of the trawl program was altered from distribution and abundance estimations to (1) identification of important species in food webs supporting commercially important crustaceans and fishes, and (2) examination of critical habitats of these organisms.

Long-lived infaunal benthic organisms should be useful as indicator species for polluted or disturbed areas because they remain in place and cannot escape a degraded habitat. Work on the clam, *Macoma balthica*, in Port Valdez, Alaska, suggested that bivalves may be good indicators of oil pollution (Shaw *et al.*, 1976). Therefore, an intensive investigation of growth rates, growth history and mortality of common subtidal clams of Cook Inlet was included in the study. Information is available for six species of clams from 34 OCSEAP stations in lower Cook Inlet.

The planktonic larval forms of many dominant crustaceans are extremely sensitive to Cook Inlet crude oil. There are numerous environmental factors such as stormy conditions, water temperature, salinity, prey availability and predator densities, which affect survival rates of crustacean larvae. However, the effects of the interactions of these variables on recruitment successes of Cook Inlet crab and shrimp larvae are undescribed. Therefore, studies of the benthic forms of the commercially important crustaceans were extended to their larvae. Preliminary information on zooplankton prey concentrations necessary for successful feeding of the first zoeae of king crab, snow crab, and pink shrimp is available. Data on the effects of starvation and water temperature on feeding success of king crab zoeae are also available. This portion of the project remains preliminary and incomplete.

RELEVANCE TO PROBLEMS OF PETROLEUM DEVELOPMENT

Oil pollution at the sea surface is a commonly observed occurrence; however, hydrocarbons can also be transported to the sea bottom and become associated with its sediments. Following a fuel oil spill in Buzzards Bay, Massachusetts, bottom sediment was contaminated to a water depth of 42 feet (Blumer *et al.*, 1971). The oil persisted within the sediments for two years after the spill (Blumer and Sass, 1972). Similarly a bunker C oil spill off Nova Scotia resulted in the oil accumulating in the sediments, and little diminution of its concentrations could be measured after 26 months following the spill (Scarratt and Zitko, 1972). Analysis of hydrocarbons in surface sediments and the clam, *Mercenaria mercenaria*, of Narragansett Bay showed that both contained hydrocarbons present in crude oil; these hydrocarbons were not present in samples from unpolluted areas (Farrington and Quinn, 1973).

Little is known concerning the effect of oil pollution on Alaskan benthic communities. A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (see Rhoads, 1974 for review). A diesel fuel spill resulted in oil becoming absorbed on sediment particles with resultant mortality of many deposit feeders on sublittoral muds. Bottom stability was altered with the death of these organisms, and a new complex of species became established in the altered substratum. The most common members of the infauna of Cook Inlet are suspension or deposit feeders; thus, oil-related mortality of these species could result in a changed near-bottom sedimentary regime with subsequent alteration of species composition. If such a change were to occur, the food webs supporting the existing species would likewise be altered.

It is possible that organisms feeding on detritus, and thus ingesting large amounts of oil contaminated sediments or on detrital feeding prey could concentrate hydrocarbons in their tissues. Concentration of hydrocarbons in the tissues of several bivalve species has been demonstrated. The clam, *Macoma balthica*, can acquire hydrocarbons from oil contaminated sediments (Shaw *et al.*, 1976). Mussels, *Mytilus edulis*, can accumulate hydrocarbons in excess of 1,000 times the exposure levels (Fossato and Canzonier, 1976). Bivalve molluscs are an important component of the infauna of lower Cook Inlet.

The importance of detrital-sediment feeding and, the potential for ingestion of hydrocarbons by the commercially important crustaceans and their prey, was unknown prior to the present project. Therefore, a program of trawl, grab and dredge sampling designed to obtain specimens for stomach analysis and information on predator and prey species abundance was initiated. The amount of sediment present in stomachs of species identified as potentially dependent on detrital feeding by microscopic analysis was analyzed. The data identify the organisms that would be expected to ingest significant amounts of oil contaminated sediment. The major prey species that could transfer hydrocarbons to crab and shrimp and some fish predators were also identified.

It is known that the moulting success of the snow crab decreases in the presence of crude oil (Karinen and Rice, 1974). Snow crab are the dominant epibenthic invertebrates in Cook Inlet.

The larvae of the commercially important crab and shrimp are killed by low concentrations of oil pollution (Rice *et al.*, 1976). However, in order to separate mortality due to oil-related activities and naturally occurring factors such as temperature and prey availability, it was necessary to first examine the interactions of the factors responsible for natural mortality. Therefore, studies of the effects of zooplankton prey availability and seawater temperature on the feeding success of the zoeae of king crab, snow crab and pink shrimp were initiated. The results of this work compliments existing data on the toxicity of oil to these zoeae (Rice *et al.*, 1976).

Because of the ability of bivalve molluscs to accumulate hydrocarbons, information on growth and mortality of common bivalves was collected. This type of data, in conjunction with tissue analysis (see Shaw *et al.*, 1976), can provide an adequate program for monitoring environmental degradation in areas where population monitoring is not feasible.

III. CURRENT STATE OF KNOWLEDGE

Few data concerning the biology, other than crab and shrimp surveys, of the benthos of Cook Inlet were available until recent OCSEAP studies were initiated. The U.S. Bureau of Commercial Fisheries (National Marine Fisheries Service) have conducted distribution and abundance surveys in this area on shrimps and crabs since 1958 (see references below). More recent investigations on larval and/or adult stages of shellfish species have been carried out (Hennick, 1973; ADF&G, 1976; Feder, 1977). A detailed examination of the food of snow crabs from lower Cook Inlet is included in Paul *et al.* (1979a). Data on non-commercial, benthic invertebrates are not as extensive as that available for commercial species in lower Cook Inlet (U.S. Bureau of Commercial Fisheries, 1958, 1961, 1963 cited in U.S. Dept. Interior 1977; Feder, 1977). Publications subsequent to OCSEAP work include information on: the distribution of crab and shrimp larvae (Haynes, 1977) and post-larval king crab (Sundberg and Clausen, 1977); food of shrimp (Crow, 1977) and a benthic faunal reconnaissance (Driskell, 1977) in Kachemak Bay. The final report of other incompleted OCSEAP studies will include information on benthic bacteria (Griffiths and Morita, OCSEAP Final Report, in press; Atlas OCSEAP Final Report, in press); fishes (Blackburn and Jackson, OCSEAP Final Report, in press); shallow water benthos (Lees and Rosenthal, OCSEAP Final Report, in press); and meroplankton (English, 1979).

Descriptions of various aspects of the physical oceanography of Cook Inlet appear in several publications and reports (Knull and Williamson, 1969; Kinney *et al.*, 1970; Evans *et al.*, 1972; Gatto, 1976; Burbank, 1977; and Muench *et al.*, 1978; Fig. III.1). In spring and summer, Gulf of Alaska water enters lower Cook Inlet through Kennedy Entrance at the southeast, flows both north and west following bathymetry before merging with a strong southerly flow on the western side of the inlet (Muench *et al.*, 1978 and Gatto, 1976). Data presented by Knull and Williamson (1969) suggest a gyre system in outer Kachemak Bay. Burbank (1977) described a large clockwise gyre in the western half of the outer bay and a slightly smaller counter clockwise gyre occurred in the eastern half. Knull and Williamson (1969) estimated a flushing time for the entire Kachemak Bay of 27 days. This relatively long residence time of water is a factor which contributes to the development of a large May to August phytoplankton population in outer Kachemak Bay (Larrance and Chester, 1979). This prolonged period of high rates of primary production results in a large input of organic matter to the bottom of Kachemak Bay throughout the summer and helps to explain the large populations of crab and shrimp found there. In the rest of the Inlet the water is more throughly mixed and phytoplankton populations are diluted resulting in considerably lower levels of plant production and organic input to the bottom (Larrance and Chester, 1979). The contribution of detritus of terrestial origin to Cook Inlet remains to be described.

IV. STUDY AREA

The established stations for Cook Inlet are tabulated in Table IV.I and Fig. IV.1.

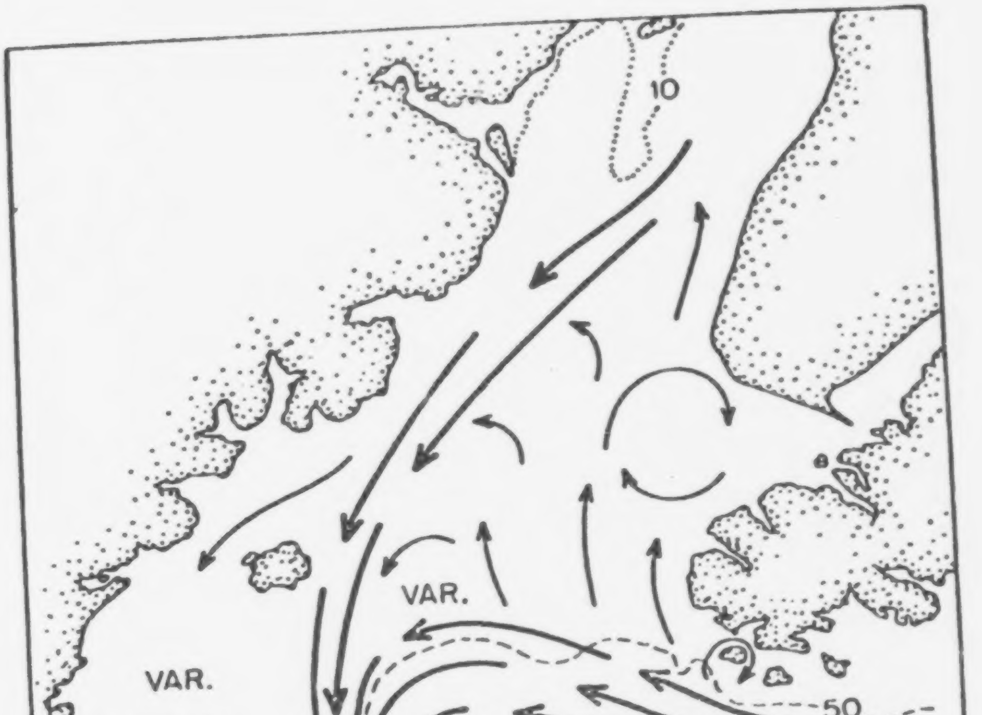

10
VAR.
VAR.
VAR.
50
50
50

Figure III.1. Diagram of spring and summer mean flow in lower Cook Inlet (after Muench *et al.*, 1978).

TABLE IV.I

LOWER COOK INLET BENTHIC STATIONS

Station Name	Latitude	Longitude	Depth (m)
2	59°00.3'	152°11.6'	117
3	59°00.3'	152°21.6'	123
4	59°00.3'	152°30.0'	152
5	59.00.3'	152°42.5'	166
5A	59°00.3'	152°47.5'	181
6	59°00.3'	152°49.7'	166
7	59°00.3'	153°03.1'	150
8	59°00.3'	153°10.6'	121
8B	59°01.0'	153°13.0'	111
9	59°08.4'	152°04.2'	129
11	59°06.0'	152°20.0'	116
12	59°08.9'	152°26.1'	121
14	59°10.3'	152°47.1'	146
15	59°10.0'	152°54.0'	139
16	59°09.8'	153°06.9'	91
17	59°10.0'	153°13.5'	67
18	59°09.3'	153°24.8'	44
19	59°15.5'	152°10.7'	110
21	59°15.3'	152°26.6'	90
23	59°15.3'	152°49.3'	91
25	59°15.9'	153°08.5'	59
26	59°15.8'	153°20.0'	42
27	59°15.6'	153°33.8'	32
28	59°15.4'	153°40.0'	31
29	59°22.6'	152°09.4'	81
30	59°21.5'	152°24.1'	81
31	59°23.3'	152°35.7'	73
33	59°22.3'	153°05.0'	53
35	59°24.9'	153°17.7'	42
36	59°30.0'	153°15.7'	33
37	59°41.3'	151°11.1'	59
39	59°34.9'	151°30.4'	99
40	59°33.1'	151°46.8'	69
40A	59°36.7'	151°51.6'	31
40B	59°39.0'	151°51.9'	33
41	59°32.7'	151°55.3'	35
42	59°32.1'	151°04.5'	40
42A	59°33.8'	152°12.5'	32
44	59°33.1'	152°13.7'	68
44A	59°33.1'	152°18.6'	61
45	59°32.7'	152°25.5'	57
45A	59°27.6'	152°26.0'	57
46	59°33.5'	152°35.5'	81

TABLE IV.I

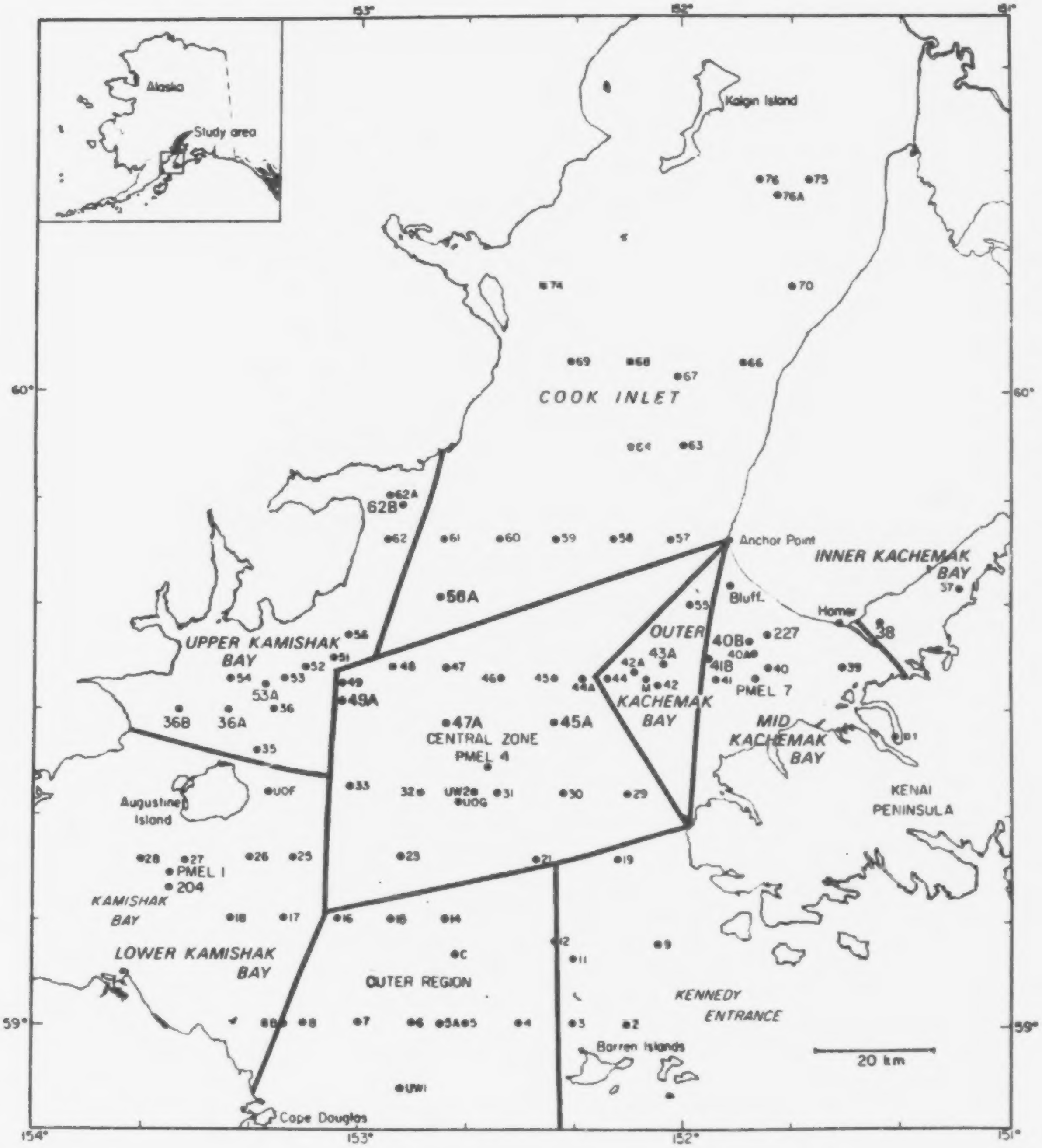
CONTINUED

Station Name	Latitude	Longitude	Depth (m)
47	59°33.9'	152°43.7'	55
47A	59°28.2'	152°44.1'	68
48	59°34.0'	152°54.0'	42
49	59°33.1'	153°04.0'	37
49A	59°29.1'	153°01.1'	-
51	59°35.0'	153°05.0'	36
52	59°34.0'	153°10.0'	35
53	59°31.8'	153°11.0'	37
54	59°33.4'	153°24.5'	24
55	59°40.0'	151°59.5'	29
56	59°37.0'	153°02.0'	35
56A	59°41.7'	152°58.0'	31
57	59°45.1'	152°03.3'	35
58	59°46.1'	152°13.0'	58
59	59°46.2'	152°23.4'	82
60	59°46.8'	152°34.7'	38
61	59°47.0'	152°43.7'	34
62	59°46.2'	152°55.0'	26
62A	59°49.8'	152°52.3'	24
62B	59°48.9'	152°49.6'	-
63	59°55.7'	151°58.6'	31
64	59°54.9'	152°08.9'	60
66	60°03.3'	151°48.3'	44
67	60°01.5'	152°01.0'	51
68	60°02.8'	152°13.3'	60
69	60°03.3'	152°20.5'	55
70	60°10.3'	151°39.8'	41
74	60°10.0'	152°23.3'	55
75	60°20.3'	151°34.5'	27
76	60°20.0'	151°46.0'	27
76A	60°18.3'	151°45.2'	47
C	59°07.5'	152°46.1'	147
M	59°32.9'	152°08.2'	48
UW1	58°53.1'	152°51.4'	172
UW2	59°22.7'	152°42.6'	-
UOF	59°21.0'	153°15.2'	44
UOG	59°20.8'	152°43.8'	68
E1	59°22.2'	153°23.1'	27
E2	59°22.0'	153°05.0'	27
N1	59°27.4'	153°23.1'	25
N2	59°28.2'	153°22.0'	27
N3	59°29.5'	153°23.1'	25
NE1	59°24.8'	153°18.1'	43

TABLE IV.I

CONTINUED

Station Name	Latitude	Longitude	Depth (m)
NE2	59°26.8'	153°14.3'	55
NE3	59°28.9'	153°10.5'	43
350	57°31.5'	155°36.0'	176
358	57°20.4'	154°57.2'	203



Alaska
Study area
Kalgin Island
COOK INLET
Anchor Point
Bluff
Homer
INNER KACHEMAK BAY
OUTER KACHEMAK BAY
MID KACHEMAK BAY
KENAI PENINSULA
UPPER KAMISHAK BAY
CENTRAL ZONE
PMEL 4
PMEL 7
PMEL 1
Augustine Island
KAMISHAK BAY
LOWER KAMISHAK BAY
OUTER REGION
KENNEDY ENTRANCE
Barren Islands
Cape Douglas
20 km
154°
153°
152°
151°
60°
59°

Figure IV.1. Lower Cook Inlet Benthic Stations and regions for grouping data for 1976, 1977 and 1978 (Feder *et al.*, 1980).

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Sampling (Table V.I) was accomplished with an Eastern otter trawl (12.2 m), try-net (3.6 m), Agassiz trawl (1.6 m). This variety of trawls was necessary because of differences in bottom type and capability of ships to deploy the nets. Infauna was collected with a pipe dredge, and van Veen grab. All three trawl types differed in their efficiency of capturing the different benthic species (see Appendix 1). Preliminary workup of trawl material was accomplished onboard ship. Live weights were obtained on the ship. All dredge and grab materials were washed on 1.0 mm screens. All invertebrates were given tentative identifications, and representative samples of individual species were preserved in 10% buffered formalin, and labeled for final identification at the Institute of Marine Science and the Marine Sorting Center, University of Alaska. Trawl data from the R/V *Moana Wave* must be considered very qualitative because the navigational system used proved to be inadequate. Try-net data were used primarily to compare the fauna of different areas because this was the only trawl that could be successfully deployed by all of the various ships utilized for sampling.

Final analysis of material was accomplished in the laboratory in Fairbanks and Seward, and the Marine Sorting Center, University of Alaska, by methods developed in past offshore OCSEAP studies. All species were assigned Taxon Code numbers, and summarized according to computer programs developed for benthic studies by Grant Matheke and the Data Processing Section of the Institute of Marine Science, University of Alaska.

Samples were collected using a 0.1 m^2 van Veen grab weighted with 50 kg of lead to facilitate penetration where they were washed through a 1.0 m screen. Samples were transferred to plastic bags then fixed and preserved in 10% Hexamine-buffered formalin. Samples were then transferred to the Institute of Marine Science in Fairbanks for identification and analysis.

In Seward, the samples were washed through a 1 mm mesh screen to remove the formalin and any remaining sediment and then rough sorted using a magnified sorting lamp. Specimens were identified using a Wild dissection microscope of 60x to 500x magnifications. A compound microscope of 100x to 1000x magnifications was used, as needed, to assist in the identifications. A wet weight was taken of each identified species using a Mettler balance. Samples were recombined and catalogued for future use, should this be necessary. A voucher collection was made, in which representatives of each identified specimen were preserved; this collection is housed at the Institute of Marine Science, Fairbanks.

Site groups and species assemblages were identified using cluster analysis. Cluster analysis can be divided into three basic steps.

1. Calculation of a measure of similarity or dissimilarity between entities to be classified.
2. Sorting through a matrix of similarity coefficients to arrange the entities in a hierarchy or dendrogram.
3. Recognition of classes within the hierarchy.

Data reduction prior to calculation of similarity coefficients consisted of elimination of taxa that could not be identified to genus and all taxa which were collected at only one station and which accounted for less than 10% of the total biomass or individuals at that station.

The coefficient used to calculate similarity matrices for cluster analysis routines was the Czekanowski coefficient[1]

Czekanowski Coefficient

$Cs_{1,2} = \frac{2W}{A + B}$ where A = the sum of the measures of attributes of entity one

B = the sum of the measures of attributes of entity two

W = the sum of the lesser measures of attributes shared by entities one and two.

The Czekanowski coefficient has been used effectively in marine benthic studies by Field and MacFarlane (1968), Field (1969, 1970 and 1971), Day

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[1] The Czekanowski coefficient is synonymous with the Motyka (Mueller-Dombois and Ellenberg, 1974), and Bray-Curtis (Clifford and Stephenson, 1975) coefficients.

et al. (1971), Stephenson and Williams (1971), and Stephenson *et al.* (1972). This coefficient emphasizes the effect of dominant species on the classification, and is often used with some form of transformation. The Czekanowski coefficient was used to calculate similarity matrices for normal cluster analysis (with sites as the entities to be classified and species as their attributes) and inverse cluster analysis (with species as entities and sites as attributes) using both untransformed and natural logarithm transformed abundance data (individuals/m^2). The natural logarithm transformation, $Y = ln(X+1)$, reduces the influence that dominant species have on the similarity determination.

Dendrograms were constructed from the similarity matrices using a group-average agglomerative hierarchical cluster analysis (Lance and Williams, 1966). Two-way coincidence tables comparing station groups formed by normal analysis and species groups formed by inverse analysis were constructed as an aid in the interpretation of dendrograms formed by cluster analyses (Stephenson *et al.*, 1972). In each table the original species x stations data matrix was rearranged (based on the results of both normal and inverse analysis) so that the stations or species with the highest similarities were adjacent to each other.

Species diversity can be thought of as a measurable attribute of a collection or a natural assemblage of species, and consists of two components: the number of species or "species richness" and the relative abundance of each species or "evenness". The two most widely used measures of diversity which; include species richness and evenness are the Brillouin (Brillouin, 1962) and Shannon (Shannon and Weaver, 1963) information measures of diversity (Nybakken, 1978). There is still disagreement of the applicability of these indices, and the results are often difficult to interpret (Sager and Hasler, 1969; Hurlbert, 1971; Fager, 1972; Peet, 1974; Pielou, 1966a, b). Pielou (1966a, b, 1977) has outlined some of the conditions under which these indices are appropriate.

The Shannon Function

$$H' = -\sum_i p_i \log p_i \quad \text{where } p_i = \frac{n_i}{N}$$

where n_i = number of individuals in the i^{th} species

N = total number of individuals

Assumes that a random sample has been taken from an infinitely large population whereas the Brillouin function

$$H = \frac{1}{N} \log \frac{N!}{n_1!n_2!\cdots n_s!}$$

is appropriate only if the entire population has been sampled. Thus, if we wish to estimate the diversity of the fauna at a sampling site the Shannon function is appropriate. The Brillouin function is merely a measure of the diversity of the five grab samples taken at each site, and makes no predictions about the diversity of the benthic community that the samples were drawn from. The evenness of samples taken at each site can be calculated using the Brillioin measure of evenness, $J = H/H_{maximum}$, where H = Brillouin diversity function. $H_{maximum}$, the maximum possible diversity for a given number of species, occurs if all species are equally common and is calculated as:

$$H_{maximum} = \frac{1}{N} \log \frac{N!}{\{[N/s]!\}^{s-r}\{([N/s]+1)!\}^{r}}$$

where [N/s] = the integer part of N/s
s = number of species in the censused community
r = N - s[N/s]

Theoretically the evenness component of the Shannon function can be calculated from the following:

$$J' = \frac{H'}{\log s*}$$

where H' = Shannon diversity function
s* = the total number of species in the randomly sampled community

However, s* is seldom known for benthic infaunal communities. Although the theoretical basis for the Shannon and Brillouin diversity indices differ, they have been shown to be closely correlated and were calculated in the present study (see discussions in Loya, 1972 and Nybakken, 1978). Species richness (Margalef, 1958) was calculated as:

$$SR = \frac{(S-1}{\ln N}$$

where S = the number of species
N = the total number of individuals

Crabs and shrimps, for stomach analysis, were captured with trawls during the period of October 1976 to July 1978. Stations selected for study were those where the species examined were abundant. The stomachs of snow, king and dungeness crabs were removed immediately after capture and examined with a dissection microscope on shipboard or in the laboratory. Shrimp and hermit crabs were fixed in 10% formalin on the ship and examined in the laboratory at a later date. A dissection microscope was used to examine hermit crab stomachs. Both dissection and compound microscopes (100x) were utilized to examine the shrimp, post-larval king crab and small snow crab stomachs. The latter method facilitates identification of diatoms, polychaete setae and small fragments. Percent frequency of occurrence was computed based on the total number of stomachs examined. Additional sampling at each station with dredges, grabs, and fine mesh nets captured prey organisms, and facilitated identification of stomach contents. Stomachs of fishes were primarily examined on shipboard, and frequency of occurrence data tabulated.

Post-larval king crab were collected by the Alaska Department of Fish and Game Marine and Coastal Habitat Management group with a bottom skimmer and a diver operated suction dredge (Sundberg and Clausen, 1977). The crabs were fixed in a solution of equal parts glycerine, isopropanol, and water. Standard length and width measurements were taken for each post-larval king crab. The stomachs were then dissected out, placed on a microscope slide, opened, and the entire contents left on the slide. The stomach contents were viewed at 100x to 400x magnifications, using a compound microscope and the contents were identified to the lowest taxa possible. Whole food items were counted when possible.

The percent fullness of snow crab stomachs was examined by injecting stomachs with water until full, then emptying the contents into graduated centrifuge tubes, centrifuging and then determining the percent of total volume that consisted of food material.

Analysis of the gut sediment content of snow crab, shrimps and hermit crabs was performed on a dry weight basis. The stomach contents of each species from selected stations was dried at 60°C, weighed, digested with

10% potassium hydroxide, and treated with concentrated hydrochloric acid to eliminate shell and carapace fragments. The sample was redried and weighed. The sediment component was then calculated as the initial dry weight of contents divided by the final dry weight and expressed as a percentage. A control with known dry weights of sand and tissue was also evaluated by this method. The control evaluation showed the sediment analysis technique to be accurate to within 2%, with the error resulting in underestimation of sediment content. Sediment weight determined by this method is, therefore, conservative since carbonates naturally associated with the sediment are eliminated.

Concentration of zooplankton prey necessary for successful feeding of king crab, snow crab, and pink shrimp zoeae were determined. Egg-bearing females from Cook Inlet were held at the Seward Marine Station on Resurrection Bay until hatching occurred. Seawater came from a depth of 75 m. Water temperatures ranged from 5° to 6°C, and salinity from 32 to 33.5°/ₒₒ. Zoeae were held in containers with wild plankton (concentrations 1,000 per liter) as food for three days before initiation of experiments. Zoeae were placed in beakers (12.5 cm high, 9 cm diameter) containing 500 ml filtered seawater, at concentrations of five zoeae per beaker. The beakers were kept in a 12-hour light, 12-hour dark cycle. During the light period prey tended to congregate, but dispersed randomly in the dark. The beakers were kept in a 4,000 liter water bath to maintain temperature. Zoeae were moved to new beakers each day with freshly counted prey. Copepods which passed through a 0.5 mm^2 screen were isolated and fed to the zoeae. Prey concentrations in the beakers were 0, 20, 40, 80 and 160 organisms per liter. A dissection microscope was used to count prey. Observations of the feeding activity of king crab, snow crab, and pink shrimp zoeae lasted 11, 10, and 13 days respectively. Experiments were terminated when the first zoeae began to moult. If a zoea died, it was removed but not replaced. Prey concentrations in beakers were kept at original levels reagardless of the number of zoeae present by adding the requisite number of prey each day. A standard one-way analysis of variance (Snedecor, 1956) was utilized to compare feeding rates at different prey concentrations.

The effect of starvation on later ability of king crab zoeae to capture zooplankton prey was determined. A female with hatching eggs captured in Cook Inlet, Alaska, was placed in a tank with static water at 5:00 p.m. Temperature was kept at 5°C. Stage one zoeae were removed for experiments the following morning at 8:00 a.m. and hatching time was assumed to be 12:00 a.m. Zoeae were placed in beakers (125 mm high, 90 mm diameter) containing 500 ml filtered seawater, salinity 33‰, at concentrations of 5 zoeae per beaker. The outside of the beakers were covered with black plastic and a light source of 350 lux maintained directly overshead 24 hours a day. The temperature in three beakers was maintained at 2°C (standard deviation = 0.0°C), while two similar sets of three beakers each were held at 4°C (standard deviation = 0.0°C) and 6°C (standard deviation = 0.8°C), respectively. The zoeae in one beaker of each temperature group received food immediately, age assumed 12 hours and every 24 hours thereafter. The zoeae in the second and third beakers of the three temperature groups were first fed after 60 hours (2.5 days) and 84 hours (3.5 days) of starvation, respectively.

The prey for zoeae studies consisted of wild copepods and copepodids primarily of the genera *Pseudocalanus*, *Acartia*, and *Oithona* that passed through a 0.5 mm^2 screen but were retained by a 0.35 mm^2 screen. The average total length of prey organisms was 0.8 mm with a standard deviation of 0.1 mm. Feeding was accomplished by placing the zoeae in beakers containing 50 prey organisms (prey concentration = 100 per liter). Thereafter, each day, the zoeae were moved to new beakers with 50 fresh prey. A gentle flow of air which passed through an air stone at the bottom of each beaker was utilized to keep prey randomly dispersed and to prevent them from settling. The air flow was adjusted so it did not interfere with the swimming of the zoeae.

Predation rates were determined by counting the number of prey remaining after 24 hours of feeding. Three control beakers containing prey but no predators were used to check the accuracy of the counting method. All prey in control beakers were accounted for during the recount. All enumeration of prey was done with a dissection microscope. Feeding observations were continued for seven days Regression analysis (Snedecor, 1956) was used to examine the relationship between the number of hours starved before feeding and the number of prey killed. The data used in the analysis include all daily feeding observations for all three temperature groups. The validity of the correlation coefficient (r) was measured using the formula $t = \sqrt{vr^2/(1-r^2)}$ where $v = n-2$.

Clams for growth studies were collected in lower Cook Inlet in April and October 1976 mainly with a 0.1 m^2 van Veen grab, and pipe dredge (36 x 91 cm) on the R/V *Moana Wave* and NOAA ship *Miller Freeman*. Occasionally, clams were obtained with a trawl or clam dredge. A try-net was used to collect empty shells of *Spisula polynyma*. Alaska Department of Fish and Game, Homer Office, supplied samples of fresh, frozen *S. polynyma* from four Cook Inlet (Kachemak Bay) stations sampled with an anchor dredge[2]. Grab and pipe dredge samples were washed on a 1 x 1 mm mesh screen, and bivalve species were separated from other benthic organisms. The screen retained all but recently settled clams.

Six relatively abundant species--*Nucula tenuis*, *Nuculana fossa*, *Glycymeris subobsoleta*, *Spisula polynyma*, *Macoma calcarea* and *Tellina nuculoides*--were selected for detailed study. Some of the clams collected could not be aged due to their damaged condition. Not all stations were used in the clam aging studies; however, all stations at which a species was collected are included in the distribution maps. All clams used for aging were pooled, i.e., clams from all sampling gear and all collection dates. Aging was accomplished by the annular method (Weymouth, 1923) using a Nikon dissection microscope and a 2x lens. Annuli, a series of closely spaced concentric growth rings, are the result of slow growth at low winter temperatures (Paul and Feder, 1973). The term 0 age group refers to individuals of the settling year class that have undergone one growing season (5 to 6 months) before forming their first winter annulus. Thus, individuals referred to as 1 year of age are actually 17 or 18 months old, and have lived through two growing seasons. The 0 annulus was not measured, except on 0 age clams, because of abrasion of the umbo on most of the older shells. Two types of measurements were made on all clams: total shell length (in millimeters) of each specimen and length (in millimeters) at each annulus. Growth history tables were generated from the measurements of length at each annulus. The last annulus on all specimens in the collection was formed in the winter of 1975-1976, and length values for this annulus were assigned to the year 1976 in growth-history tables. Selected growth history tables for each clam species are included in this report.

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[2] See Alaska Department of Fish and Game, Homer, for station locations.

Age-structure tables were generated; only stations with 10 or more specimens of a given species are included in individual station tables. In addition, tables are presented that include a summary of age-structure for each species from all stations where it was collected.

All data were processed by a Honeywell 66/40 computer. Mean shell length, range, standard deviation, and standard error of the mean were plotted to show the relationship between shell length and age. The horizontal line in the latter plot is the mean, the vertical line is the range, the white box is the standard deviation, and the black box the standard error of the mean. The standard error of the mean and the standard deviation are not shown for age classes with a sample size of five or less.

Pipe dredge samples were collected at stations with relatively large numbers of clams. These samples were frozen. The six species of clams were removed from the frozen sediment and aged. Selected specimens from each age group were dried whole at 60°C until a constant weight was reached. Ten percent KOH was used to dissolve the tissues of these dried clams. The shells were then rinsed in distilled water and redried at 60°C until a constant weight was observed. Dry meat weight was calculated by subtracting shell weight from total dry weight. The mean numbers of clams in each age class present in grab samples were multiplied by the mean dry meat weights at the appropriate age. Calculated dry meat weights of each age class were added to obtain total clam tissue dry weight or biomass at a station.

Mortality rates were determined by the use of Gruffydd's (1974) technique. That latter technique, developed to determine mortality in scallops, assumes that although recruitment varies from year to year at a particular station, overall recruitment to a large area is fairly constant. With this assumption, the toal number of specimens for *Nucula tenuis*, *Nuculana fossa*, *Glycymeris subobsoleta*, *Macoma calcarea*, and *Tellina nuculoides* from all stations' samples were plotted against age. These curves eliminate the effect of uneven recruitment apparent in individual samples. Utilizing the number of individuals estimated from the curve rather than the actual catch, the percent mortality (Z) is estimated using the expression, $Z = N_{t+1} = N_t \cdot e^{-z(t)}$; where N = number of clams, t = time, t+1 = time at the next year, z = mortality coefficient, and e = 2.718. The mortality curves were drawn by computer, a modification from Gruffydd's (1974) technique where the curves are plotted by eye on semi-log graph paper.

TABLE V.I

BENTHIC STATIONS SAMPLED AND TYPE OF GEAR USED IN LOWER COOK INLET

Station Name	Pipe Dredge	Agassiz Trawl	Try-net	van Veen Grab	Eastern Otter Trawl
2	X	-	-	-	-
3	X	-	-	-	-
4	X	-	-	-	-
5	X	X	X	X	X
5A	-	X	-	-	-
6	X	X	X	X	-
7	X	X	X	X	X
8	X	X	X	X	X
8B	-	X	-	-	-
9	X	-	-	-	-
11	X	-	-	-	-
12	X	-	-	-	-
14	X	-	X	-	X
15	-	-	-	-	-
16	X	-	-	-	-
17	-	-	-	-	-
18	X	-	X	X	X
19	X	-	-	-	-
21	X	-	-	-	-
23	X	-	X	-	X
25	X	-	X	-	X
26	-	-	-	-	-
27	X	-	X	X	X
28	X	-	X	X	X
29	X	-	-	-	-
30	X	-	-	-	-
31	X	-	-	X	-
33	X	-	-	X	-
35	X	X	X	-	-
36	-	-	X	-	-
37	X	X	X	-	-
38	-	-	X	-	-
39	X	-	X	-	-
40	X	-	X	X	-
40A	X	X	X	X	X
41	X	X	-	-	X
42	X	X	X	X	-
42A	X	-	-	-	-
44	X	-	X	-	-
44A	X	X	-	-	-
45	X	-	-	X	-
46	X	-	-	X	-
47	X	-	-	-	-
48	X	-	-	X	-

TABLE V.I

CONTINUED

Station Name	Pipe Dredge	Agassiz Trawl	Try-net	van Veen Grab	Eastern Otter Trawl
49	X	X	X	X	-
51	-	-	X	-	-
52	-	-	X	-	-
53	X	X	X	-	X
54	X	-	X	X	X
55	X	-	X	-	-
56	-	-	X	-	-
57	X	-	-	-	-
58	X	-	-	-	-
59	X	-	-	-	-
60	X	-	-	-	-
61	X	-	-	-	-
62	X	-	X	-	-
62A	X	-	X	-	X
62B	X	-	X	-	-
63	X	-	-	-	-
64	X	-	-	-	-
66	X	-	-	-	-
67	X	-	-	-	-
68	X	-	-	-	-
69	X	-	-	X	-
70	X	-	-	-	X
74	X	-	-	-	-
75	X	-	-	-	-
76	-	-	-	-	-
76A	X	-	-	-	X
C	X	-	-	-	-
M	X	-	-	-	-
UW1	X	-	-	-	-
UW2	X	-	-	-	-
UOF	X	-	-	-	-
UOG	X	-	-	-	-
PMEL1	-	X	X	X	-
PMEL2	-	X	X	X	-
PMEL3	-	X	X	X	-

VI. RESULTS AND DISCUSSION

SECTION A - TRAWL AND GRAB PROGRAM FOR LOWER COOK INLET

Biomass by Area for Trawl Samples

The average invertebrate epifaunal biomass values reported for lower Cook Inlet, 2.41 g/m^2 (Table VI.A.I), in the present study are similar to biomass estimations of 2.6 g/m^2 determined for the northeast Gulf of Alaska (Jewett and Feder, 1976). Figure IV.1 illustrates station positions discussed in this section. (Also, see Feder *et al.*, 1978 for biomass distribution maps of 1976 cruise data.)

Three of the ten most productive stations (5A, 6, 23) are included in the oil-gas lease area (Fig. IV.1). The majority of the stations in the central zone lease area had untrawlable bottoms and sampling in the area was restricted to three stations. In a ranking from highest to lowest weight of invertebrates (g/m^2) for the 41 stations, these three stations (23, 49 and PMEL 4) ranked 10th, 13th, and 28th (Table VI.A.I), respectively.

On a regional basis the weight of invertebrates captured by trawl in inner Kachemak Bay averaged 0.75 g/m^2 (Table VI.A.II). However, due to the large size of the ships used, sampling was restricted to three stations and the data may not be representative of the whole area. In the remainder of Kachemak Bay (Tables VI.A.III, VI.A.IV) invertebrate live weight averaged 2.45 g/m^2 and 9.13 g/m^2 in the middle and outer regions of the Bay, respectively. The latter figure was the highest biomass estimation of all of the regions of Cook Inlet examined (Fig. IV.1).

In the central zone of the Inlet (Fig. IV.1) the average weight of invertebrates, 1.77 g/m^2 (Table VI.A.V), was below the average of 2.41 g/m^2 (Table VI.A.I) for the whole of lower Cook Inlet and less than half that of Kachemak Bay. The invertebrate biomass, 2.62 g/m^2 (Table VI.A.VI) in the outer region (Fig. IV.1) of the Inlet was similar to the average for all of lower Cook Inlet, 2.41 g/m^2. The average biomass of invertebrates, 2.11 g/m^2 Table VI.A.VII) in lower Kamishak Bay (Fig. IV.1) was higher than upper Kamishak Bay, 1.18 g/m^2 (Table VI.A.VIII) and both were below the average, 2.41 g/m^2, for lower Cook Inlet. Table VI.A.IX provides a ranking of invertebrates wet weights for the seven areas sampled. Weights (g/m^2) and numbers (per km fished) of selected organisms are also included in Section D.

Species Composition by Area for Trawl Samples

Generally, three to four species dominated the invertebrate fauna captured by trawls at individual stations in lower Cook Inlet (Tables VI.A.II-VI.A.VIII). In twenty-three of the stations, the three most abundant taxa accounted for more than 80% of all organisms captured (Tables VI.A.II-VI.A.VIII). Similarly, the three most abundant taxa accounted for over 80% of the total weight at 26% of the stations and 70% of the weight at 17% of the stations.

In inner Kachemak Bay the pandalid shrimps *Pandalus borealis* (pink shrimp), *P. goniurus* (humpy shrimp) and *P. hypsinotus* (coonstripe shrimp) dominated the catch in terms of number (Table VI.A.II). In terms of weight, *P. borealis* and *P. hypsinotus* were the dominant organisms.

In mid-Kachemak Bay (Fig. IV.1) *Pandalus borealis, Crangon dalli* and the sea cucumber, *Cucumaria fallax* were numerically most abundant (Table VI.A.III). *Chionoecetes bairdi* (snow crab), *P. borealis, Cancer magister* (dungeness crab) and the sea pen (*Ptilosarcus gurneyi*) were the most abundant organisms by weight in the area (Table VI.A.III). In outer Kachemak Bay the echinoderms *C. fallax* and *Strongylocentrotus droebachiensis* (sea urchin), plus the sand dollar, *Echinarachnius parma*, dominated both in numbers and weight (Table VI.A.IV). King crab (*Paralithodes camtschatica*) was dominant at Station 43A.

In the central zone of Cook Inlet (Fig. IV.1) each station was dominated numerically by different organisms with *C. bairdi, Crangon* spp. (sand shrimps), *E. parma* and *P. guneyi* generally important (Table VI.A.V). In the outer Cook Inlet region between Shaw Island and the Barren Islands *C. bairdi* and *P. camtschatica* were most abundant in terms of weight. In this area *C. bairdi* and crangonid shrimps were numerically abundant (Table VI.A.VI).

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The crangonidae and *C. bairdi* were also numerically abundant in lower Kamishak Bay. *Chionoecetes bairdi* was the dominant organism in terms of weight (Table VI.A.VII). In upper Kamishak Bay *Crangon dalli* was the most abundant organism at five of the ten stations sampled. *Strongylocentrotus droebachiensis*, *Pandalus goniurus*, and *C. bairdi* were dominant at one station each. The weight composition at four stations was dominated by *C. bairdi* while *S. droebachiensis*, *P. goniurus*, and *C. dalli* were dominant at one station each (Table VI.A.VIII). A general summary of Cook Inlet taxa captured by trawl appears in Tables (VI.A.IX, VI.A.X, and VI.A.XI.

Further information on distribution of 14 dominant species occurs in Section D. Data for individual stations are available from The National Oceanographic Data Center. A taxa list for nearshore benthos captured by a bottom skimmer appears in Appendix 2.

The dominant phyla in numbers per m^2, for combined data from all 41 stations, were Arthropoda (Crustacea) (91%), Mollusca (3.5%), and Echinodermata (3%). In terms of live weight the dominant groups were Arthropoda (Crustacea) (74%), Echinodermata (17%), and Mollusca (5.8%). The important species were snow crab (*Chionoecetes bairdi*) which accounted for 38.6% of the live weight and averaged 1.1 g/m^2; humpy shrimp (*Pandalus goniurus*) with 20.7% of the weight and averaging 0.6 g/m^2; king crab (*Paralithodes camtschatica*) with 7.2% of the weight averaging 0.2 g/m^2; sea cucumber (*Cucumaria fallax*) with 4.8% of the weight averaging 0.1 g/m^2; and the green sea urchin (*Strongylocentrotus droebachiensis*) which was 2.3% of the weight and averaged 0.07 g/m^2. The three crustacean species accounted for 66.5% of the weight of trawl-caught banthic invertebrates and all are currently harvested commercially. The sea cucumber and sea urchin account for an additional 7.1% of the total weight; both species may have some commercial potential. The preponderance of commercial, harvestable invertebrate species in lower Cook Inlet is reflected by the profitable fisheries found there.

Like Cook Inlet, the northeastern Gulf of Alaska invertebrate epifaunal biomass is also dominated by snow crab. Snow crab in the Gulf account for 66.2% of the live weight of benthic epifaunal invertebrates (Jewett and Feder, 1976). In the Gulf the other dominant epibenthic invertebrates in terms of weight differ from those of the Inlet with the brittle star, *Ophiura sarsi* (4.4%); *Pandalus borealis* (2.9%); *Ctenodiscus crispatus* (2.9%); *Brisaster townsendi* (2.1%); *Pycnopodia helianthoides* (2.0%); and *Pecten caurinus* (2.0%) accounting for an additional 16.3% of the live weight (Jewett and Feder, 1976).

The relatively large epibenthic invertebrate biomass in Kachemak Bay may be supported by the very high rates of primary productivity (as high as 7.8 g C per m^2 per day) that persists throughout spring and summer in this bay (Larrance and Chester, 1979). This prolonged period of primary productivity is atypical for most North Pacific areas where phytoplankton production is characterized by a short spring bloom followed by nutrient limited summer production. The total supplies of organic carbon contributed to the bottom over the March to August period in 1978 were 60 g C per m^2 at Kachemak Bay, 17 g C per m^2 in the central Inlet and 40 g C per m^2 in Kamishak Bay (Larrance and Chester, 1979). The dominant epibenthic invertebrates are capable of either utilizing this input of organic detritus directly (e.g., *Cucumaria fallax*) or, like the large predators, by feeding on organisms that are detrital feeders.

TABLE VI.A.I

A COMPARISON OF MEAN TOTAL GRAMS (LIVE WEIGHT) OF INVERTEBRATES CAPTURED BY TRAWL AT DIFFERENT STATIONS IN LOWER COOK INLET

Station	Total g per m^2	Area*
43A	14.49	Kachemak Bay
40A	8.39	Kachemak Bay
25	8.24	Kamishak Bay
42	6.70	Kachemak Bay
40B	6.50	Kachemak Bay
55	6.20	Kachemak Bay
5A	5.35	Outer Region
6	4.57	Outer Region
14	3.88	Outer Region
23	3.25	Central Zone
53	2.87	Kamishak Bay
54	2.70	Kamishak Bay
49	1.98	Central Zone
8	1.91	Outer Region
40	1.62	Kachemak Bay
37	1.60	Kachemak Bay
56A	1.50	Kamishak Bay
27	1.49	Kamishak Bay
18	1.42	Kamishak Bay
7	1.37	Kamishak Bay
41	1.13	Outer Zone
45A	1.07	Kachemak Bay
53A	1.00	Kamishak Bay
62	0.98	Kamishak Bay
36	0.94	Kamishak Bay
28	0.85	Kamishak Bay
5	0.83	Outer Zone
PMEL4	0.81	Kamishak Bay
35	0.63	Central Zone
227	0.61	Kamishak Bay
62A	0.57	Kachemak Bay
PMEL7	0.56	Kachemak Bay
PMEL1	0.47	Kamishak Bay
8A	0.47	Kamishak Bay
41B	0.45	Outer Zone
38A	0.43	Kachemak Bay
56	0.37	Kamishak Bay
39	0.35	Kachemak Bay
38	0.24	Kachemak Bay
204	0.22	Kamishak Bay
62B	0.18	Kamishak Bay
Mean	2.41	
Standard deviation	2.98	

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*See Fig. IV.1

TABLE VI.A.II

SUMMARY OF TRAWL DATA FOR INVERTEBRATES IN INNER KACHEMAK BAY*

Station	Number Trawls	Average Number Organisms per m^2	Three Most Abundant Taxa by Count (% count)	Average Total Weight g per m^2	Three Most Abundant Taxa by Weight (% of wt)
37	8	0.30	*Pandalus borealis* (78%) *Pandalus platyceros* (5%) *Pandalus hypsinotus* (4%)	1.60	*Pandalus borealis* (44%) *Chionoecetes bairdi* (15%) *Pandalus platyceros* (11%)
38	1	0.12	*Pandalus goniurus* (67%) *Pandalus borealis* (14%) *Pandalus hypsinotus* (9%)	0.24	*Pandalus hypsinotus* (43%) *Chionoecetes bairdi* (21% *Pandalus goniurus* (18%)
38A	1	0.15	*Crangon* sp. (45%) *Pandalus goniurus* (40%) *Pandalus hypsinotus* (13%)	0.43	*Pandalus hypsinotus* (37%) *Crangon* sp. (36%) *Pandalus goniurus* (21%)
			Mean	0.76	

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*See Fig. IV.1

TABLE VI.A.III

SUMMARY OF TRAWL DATA FOR INVERTEBRATES IN MID-KACHEMAK BAY*

Station	Number Trawls	Average Number Organisms per m^2	Three Most Abundant Taxa by Count (% count)	Average Total Weight g per m^2	Three Most Abundant Taxa by Weight (% of wt)
39	3	0.03	*Pandalus borealis* (16%) *Pandalus goniurus* (16%) *Pandalus hypsinotus* (15%)	0.35	*Chionoecetes bairdi* (55%) *Pandalopsis dispar* (5%) *Pandalus hypsinotus* (5%) *Pandalus borealis* (5%)
40	6	0.03	*Pandalus borealis* (45%) *Ptilosarcus gurneyi* (38%) *Crangon dalli* (12%)	1.62	*Cancer magister* (44%) *Ptilosarcus gurneyi* (38%) *Crangon dalli* (10%)
40A	3	0.10	*Hyas lyratus* (29%) *Nucella lamellosa* (23%) *Neptunea lyrata* (13%)	8.39	*Cucumaria fallax* (33%) *Chionoecetes bairdi* (18%) *Hyas lyratus* (15%)
40B	1	0.01	*Cucumaria fallax* (50%) *Strongylocentrotus droebachiensis* (22%) Hydrozoa (6%) Porifera (6%)	6.50	*Cucumaria fallax* (80%) Porifera (4%) Hydrozoa (3%)
41	5	0.01	*Crangon dalli* (53%) *Chionoecetes bairdi* (10%) *Cancer magister* (4%)	1.13	*Chionecetes bairdi* (58%) *Cancer magister* (19%) *Cucumaria fallax* (19%)
41B	1	0.03	*Crangon dalli* (74%) *Argis* sp. (16%) *Chionoecetes bairdi* (4%)	0.45	*Paralithodes camtschatica* (39%) *Chionoecetes bairdi* (21%) *Crangon dalli* (14%)
PMEL 7	4	0.05	*Pandalus borealis* (80%) *Crangon dalli* (7%) *Crangon* spp. (4%)	0.56	*Pandalus borealis* (46%) *Chionoecetes bairdi* (29%) *Canger magister* (9%)
227	3	0.04	*Pandalus borealis* (72%) *Crangon dalli* (19%) *Ptilosarcus gurneyi* (5%)	0.61	*Ptilosarcus gurneyi* (41%) *Pandalus borealis* (22%) *Cancer magister* (17%)
			Mean	2.45	

*See Fig. IV.1

TABLE VI.A.IV

SUMMARY OF TRAWL DATA FOR INVERTEBRATES IN OUTER KACHEMAK BAY*

Station	Number Trawls	Average Number Organisms per m^2	Three Most Abundant Taxa by Count (% count)	Average Total Weight g per m^2	Three Most Abundant Taxa by Weight (% of wt)
42	2	0.08	*Echinarachnius parma* (32%) *Strongylocentrotus droebachiensis* (17%) *Cucumaria fallax* (14%)	6.70	*Cucumaria fallax* (65%) *Strongylocentrotus droebachiensis* (13%) *Echinarachnius parma* (12%)
43A	1	0.03	*Paralithodes camtschatica* (25%) *Strongylocentrotus droebachiensis* (22%) *Cucumaria fallax* (21%)	14.49	*Paralithodes camtschatica* (74%) *Cucumaria fallax* (18%) *Metridium senile* (3%)
55	1	0.18	*Strongylocentrotus droebachiensis* (46%) *Oregonia gracilis* (30%) *Sclerocrangon boreas* (16%)	6.20	*Strongylocentrotus droebachiensis* (70%) *Cucumaria fallax* (13%) *Oregonia gracilis* (7%)
			Mean	9.13	

*See Fig. IV.1

TABLE VI.A.V

SUMMARY OF TRAWL DATA FOR INVERTEBRATES IN CENTRAL COOK INLET ZONE*

Station	Number Trawls	Average Number Organisms per m^2	Three Most Abundant Taxa by Count (% count)	Average Total Weight g per m^2	Three Most Abundant Taxa by Weight (% of wt)
23	3	0.05	*Crangon* spp. (49%) *Chionoecetes bairdi* (34%) *Argis* spp. (5%)	3.25	*Chionoecetes bairdi* (93%) *Neptunea lyrata* (3%) *Paralithodes camtschatica* (1%)
45A	1	0.04	*Echinarachnius parma* (94%) *Crangon* spp. (4%) *Natica clausa* (1%)	1.07	*Echinarachnius parma* (98%) *Natica clausa* (0.8%) *Crangon* spp. (0.5%)
49	3	0.31	*Chionoecetes bairdi* (81%) *Pandalus goniurus* (8%) *Crangon dalli* (7%)	1.98	*Chionoecetes bairdi* (59%) *Pagurus capillatus* (7%) *Pandalus goniurus* (6%)
PMEL 4	2	0.02	*Ptilosarcus gurneyi* (48%) *Echinarachnius parma* (38%) *Fusitriton oregonensis* (2%) *Crangon dalli* (2%)	0.81	*Ptilosarcus gurneyi* (59%) *Echinarachnius parma* (20%) *Leptasterias* sp. (12%)
			Mean	1.78	

*See Fig. IV.1

TABLE VI.A.VI

SUMMARY OF TRAWL DATA FOR INVERTEBRATES IN OUTER COOK INLET REGION*

Station	Number Trawls	Average Number Organisms per m^2	Three Most Abundant Taxa by Count (% count)	Average Total Weight g per m^2	Three Most Abundant Taxa by Weight (% of wt)
5	9	0.05	*Chionoecetes bairdi* (59%) *Neptunea lyrata* (6%) *Ctenodiscus crispatus* (4%)	0.83	*Chionoecetes bairdi* (40%) *Neptunea lyrata* (10%) *Strongylocentrotus droebachiensis* (6%)
5A	2	0.13	*Pandalus borealis* (34%) *Ophiura sarsi* (13%) *Crangon communis* (8%)	5.35	*Paralithodes camtschatica* (69%) *Chionoecetes bairdi* (16%) *Fusitriton oregonensis* (9%)
6	2	0.02	*Crangon dalli* (23%) *Pandalus borealis* (15%) *Chionoecetes bairdi* (8%)	4.57	*Paralithodes camtschatica* (86%) *Chionoecetes bairdi* (13%) *Crangon dalli* (0.1%)
7	2	0.04	*Pandalus borealis* (35%) *Chionoecetes bairdi* (34%) *Fusitriton oregonensis* (8%)	1.37	*Chionoecetes bairdi* (61%) *Neptunea lyrata* (17%) *Fusitriton oregonensis* (8%)
8	3	0.16	*Crangon dalli* (27%) *Chionoecetes bairdi* (26%) *Pandalus borealis* (17%)	1.91	*Chionoecetes bairdi* (36%) *Hyas lyratus* (21%) Actiniidae (13%)
8A	1	0.71	*Crangon communis* (65%) *Crangon dalli* (28%) *Pandalus borealis* (2%)	0.47	*Crangon dalli* (56%) *Crangon communis* (33%) *Pandalus borealis* (6%)
14	1	0.02	*Chionoecetes bairdi* (82%) Porifera (5%) *Neptunea lyrata* (4%)	3.88	*Chionoecetes bairdi* (90%) Actiniidae (4%) *Neptunea lyrata* (2%)
			Mean	2.63	

*See Fig. IV.1

TABLE VI.A.VII

SUMMARY OF TRAWL DATA FOR INVERTEBRATES FOR LOWER KAMISHAK BAY*

Station	Number Trawls	Average Number Organisms per m^2	Three Most Abundant Taxa by Count (% count)	Average Total Weight g per m^2	Three Most Abundant Taxa by Weight (% of wt)
18	4	0.03	Crangonidae (58%) *Chionoecetes bairdi* (30%) *Crangon dalli* (5%)	1.42	*Chionoecetes bairdi* (83%) *Paralithodes camtschatica* (3%) *Lethasterias nanimensis* (2%)
25	3	0.11	*Chionoecetes bairdi* (51%) Crangonidae (23%) *Crangon dalli* (11%)	8.24	*Chionoecetes bairdi* (94%) *Chlamys rubida* (2%) *Paralithodes camtschatica* (2%)
27	3	0.03	*Crangon dalli* (48%) *Chionoecetes bairdi* (16%) *Pagurus ochotensis* (11%)	1.49	*Chionoecetes bairdi* (48%) *Paralithodes camtschatica* (13%) *Pagurus ochotensis* (12%)
28	4	0.02	Crangonidae (44%) *Chionoecetes bairdi* (23%) *Pagurus ochotensis* (9%)	0.85	*Chionoecetes bairdi* (63%) *Paralithodes camtschatica* (11%) *Pagurus ochotensis* (9%)
204	1	0.003	*Chionoecetes bairdi* (48%) *Argis* sp. (35%) *Neptunea lyrata* (9%)	0.22	*Chionoecetes bairdi* (84%) *Neptunea lyrata* (12%) *Pagurus capillatus* (2%)
PMEL 1	7	0.02	*Crangon* spp. (39%) *Crangon dalli* (22%) *Chionoecetes bairdi* (12%)	0.47	*Chionoecetes bairdi* (54%) *Evasterias* sp. (13%) *Neptunea lyrata* (9%)
			Mean	2.11	

*See Fig. IV.1

TABLE VI.A.VIII

SUMMARY OF TRAWL DATA FOR INVERTEBRATES FOR UPPER KAMISHAK BAY*

Station	Number Trawls	Average Number Organisms per m^2	Three Most Abundant Taxa by Count (% count)	Average Total Weight g per m^2	Three Most Abundant Taxa by Weight (% of wt)
35	6	0.04	*Crangon dalli* (41%) *Pandalus goniurus* (17%) *Neptunea lyrata* (12%)	0.63	*Chionoecetes bairdi* (45%) *Neptunea lyrata* (24%) *Fusitriton oregonensis* (9%)
36	2	0.08	*Crangon dalli* (75%) *Pandalus goniurus* (7%) *Argis* sp. (4%)	0.94	*Chionoecetes bairdi* (31%) *Neptunea lyrata* (16%) *Paralithodes camtschatica* (16%) *Crangon dalli* (15%)
53	6	0.02	*Chionoecetes bairdi* (32%) *Crangon dalli* (21%) *Pandalus goniurus* (19%)	2.87	*Neptunea lyrata* (51%) *Chionoecetes bairdi* (41%) *Paralithodes camtschatica* (5%)
53A	2	0.02	*Strongylocentrotus droebachiensis* (19%) *Crangon dalli* (17%) *Modiolus modiolus* (15%)	1.02	*Strongylocentrotus droebachiensis* (43%) Cucumariidae (15%) *Fusitriton oregonensis* (9%)
54	4	0.03	*Crangon dalli* (60%) *Chionoecetes bairdi* (13%) *Neptunea lyrata* (8%)	2.73	*Chionoecetes bairdi* (42%) *Paralithodes camtschatica* (40%) *Neptunea lyrata* (7%)
56	2	0.04	*Crangon dalli* (70%) *Argis* spp. (9%) *Chionoecetes bairdi* (5%)	0.37	*Chionoecetes bairdi* (28%) *Crangon dalli* (23%) *Evasterias echinosoma* (14%)
56A	1	0.04	Brachiopoda (12%) *Sclerocrangon boreas* (11%) *Glycymeris subobsoleta* (9%)	1.51	Cucumariidae (50%) *Evasterias* sp. (15%) *Chlamys* sp. (5%)
62	1	0.20	*Crangon communis* (72%) *Pandalus goniurus* (17%) *Labidochirus* sp. (5%)	0.98	*Crangon communis* (58%) *Strongylocentrotus droebachiensis* (20%) *Pandalus goniurus* (14%)

TABLE VI.A.VIII

CONTINUED

Station	Number Trawls	Average Number Organisms per m^2	Three Most Abundant Taxa by Count (% count)	Average Total Weight g per m^2	Three Most Abundant Taxa by Weight (% of wt)
62A	6	0.13	*Pandalus goniurus* (52%) *Crangon dalli* (40%) *Chionoecetes bairdi* (1%)	0.57	*Pandalus goniurus* (24%) *Crangon dalli* (19%) *Strongylocentrotus droebachiensis* (11%)
62B	1	0.04	*Crangon dalli* (80%) *Echinarachnius parma* (18%) *Pandalus borealis* (1%)	0.18	*Crangon dalli* (50%) *Chionoecetes bairdi* (25%) *Echinarachnius parma* (24%)
			Mean	1.18	

*See Fig. IV.1

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TABLE VI.A.IX

MEAN AND RANGE OF INVERTEBRATE WET WEIGHTS TAKEN BY TRAWL IN THE SEVEN MAJOR REGIONS OF LOWER COOK INLET AND NORTHEAST GULF OF ALASKA

Sampling Area*	Mean Total g Invertebrate Live Weight per m^2	Range g per m^2 at Individual Stations
Outer Kachemak Bay	9.13	6.2 - 14.5
Outer Inlet Region	2.62	0.5 - 5.3
Mid-Kachemak Bay	2.45	0.3 - 8.4
Lower Kamishak Bay	2.11	0.2 - 8.2
Central Inlet Zone	1.78	0.8 - 3.2
Upper Kamishak Bay	1.18	0.2 - 2.9
Inner Kachemak Bay	0.76	0.2 - 1.6
Northeast Gulf of Alaska**	2.60	- -

* See Fig. IV.1

**See Jewett and Feder (1976)

TABLE VI.A.X

COOK INLET TAXONOMIC SUMMARY BY PHYLUM FOR 41 TRAWL STATIONS

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Count
Porifera	0.00081	0.9058	0.02635	0.2525
Cnidaria	0.00062	1.6715	0.04862	0.4751
Rhynchocoela	0.00005	0.0034	0.00010	0.0035
Annelida	0.00161	0.0161	0.00047	1.0648
Mollusca	0.00071	5.8723	0.17082	3.5310
Pycnogonida	0.00187	0.0002	0.00001	0.1035
Crustacea	0.00879	74.0865	2.15509	91.3006
Ectoprocta	0.00007	0.0544	0.00158	0.0351
Brachiopoda	0.00045	0.0250	0.00073	0.1159
Echinodermata	0.00098	17.3360	0.50429	3.0398
Urochordata	0.00046	0.0288	0.00084	0.0781
Total			2.9089	

TABLE VI.A.XI

COOK INLET TAXONOMIC SUMMARY BY SPECIES FOR 41 TRAWL STATIONS

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Phylum Count	% Phylum wt
Porifera	0.00081	0.91	0.02635	100.00	100.00
Hydrozoa	0.00034	0.17	0.00494	10.53	10.16
Anthozoa	0.00011	0.30	0.00861	3.05	17.71
Eunephthya rubiformis	0.00015	0.00	0.00002	0.71	0.04
Stylatula gracile	0.00006	0.00	0.00004	0.26	0.08
Pennatulacea pannalulidae	0.00038	0.01	0.00015	1.26	0.32
Ptilosarcus gurneyi	0.00202	0.67	0.01949	72.69	40.08
Actiniidae	0.00022	0.39	0.01146	9.08	23.58
Tealia crassicornis	0.00005	0.01	0.00041	0.53	0.83
Metridium senile	0.00113	0.12	0.00350	1.89	7.20
Rhynchocoela	0.00005	0.00	0.00010	100.00	100.00
Annelida	0.00057	0.00	0.00005	0.63	9.62
Polychaeta	0.00029	0.00	0.00007	3.47	14.38
Polynoidae	0.00039	0.01	0.00019	10.38	40.58
Eunoe depressa	0.00028	0.00	0.00000	0.21	0.49
Gattyana ciliata	0.00620	0.00	0.00003	4.63	5.92
Gattyana cirrosa	0.01353	0.00	0.00000	10.10	0.49
Anaitides mucosa	0.00028	0.00	0.00000	0.21	0.99
Typosyllis spp.	0.06933	0.00	0.00000	51.77	0.49
Nereis spp.	0.00050	0.00	0.00011	4.56	23.18
Sabellidae	0.00003	0.00	0.00000	0.07	0.82
Potamilla neglecta	0.00592	0.00	0.00000	4.42	0.49
Sabella spp.	0.00451	0.00	0.00000	3.37	0.49
Crucigera zygophora	0.00789	0.00	0.00000	5.89	0.99
Aphrodita japonica	0.00007	0.00	0.00000	0.11	0.25
Notostomobdella spp.	0.00005	0.00	0.00000	0.18	0.82
Mopaliidae	0.00006	0.00	0.00000	0.02	0.00
Pelecypoda	0.00007	0.00	0.00000	0.03	0.00
Nucula tenuis	0.00007	0.00	0.00001	0.10	0.01
Nuculana fossa	0.00066	0.00	0.00002	0.55	0.01
Yoldia scissurata	0.00013	0.00	0.00000	0.06	0.00
Yoldia thraciaeformis	0.00008	0.00	0.00000	0.03	0.00
Glycymeris subobsoleta	0.00104	0.00	0.00014	1.25	0.08
Modiolus modiolus	0.00107	0.15	0.00441	5.52	2.58
Pectinidae	0.00195	0.06	0.00186	2.87	1.09
Chlamys spp.	0.00133	0.03	0.00094	1.05	0.55

TABLE VI.A.XI

CONTINUED

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Phylum Count	% Phylum wt
Chlamys rubida	0.00055	0.42	0.01221	2.18	7.15
Pecten caurinus	0.00010	0.09	0.00255	0.15	1.49
Propeamussium davidsoni	0.00018	0.00	0.00000	0.10	0.00
Astartidae	0.00006	0.00	0.00000	0.04	0.00
Astarte alaskensis	0.00005	0.00	0.00002	0.06	0.01
Astarte rollandi	0.00007	0.00	0.00000	0.03	0.00
Cyclocardia spp.	0.00011	0.00	0.00001	0.16	0.00
Cyclocardia ventricosa	0.00014	0.00	0.00002	0.08	0.01
Cyclocardia crassidens	0.00004	0.00	0.00000	0.02	0.00
Cardiidae	0.00006	0.00	0.00002	0.08	0.01
Clinocardium spp.	0.00002	0.00	0.00001	0.03	0.00
Clinocardium ciliatum	0.00017	0.00	0.00010	0.48	0.06
Clinocardium nuttallii	0.00012	0.10	0.00277	0.31	1.62
Clinocardium fucanum	0.00034	0.00	0.00001	0.18	0.01
Serripes groenlandicus	0.00015	0.09	0.00274	0.93	1.60
Psephidia lordi	0.00016	0.00	0.00000	0.17	0.00
Spisula polynyma	0.00016	0.03	0.00086	0.72	0.50
Macoma spp.	0.00013	0.00	0.00003	0.28	0.02
Macoma calcarea	0.00004	0.02	0.00072	0.03	0.42
Macoma nasuta	0.00052	0.00	0.00006	0.55	0.04
Tellina nuculoides	0.00017	0.00	0.00001	0.20	0.01
Siliqua alta	0.00007	0.00	0.00004	0.15	0.02
Hiatella arctica	0.00012	0.00	0.00001	0.29	0.00
Pandora bilirata	0.00007	0.00	0.00000	0.03	0.00
Cardiomya oldroydi	0.00007	0.00	0.00000	0.03	0.00
Gastropoda	0.00046	0.05	0.00158	2.38	0.93
Bathybembix	0.00003	0.00	0.00000	0.01	0.00
Margarites costalis	0.00001	0.00	0.00000	0.01	0.00
Solariella obscura	0.00007	0.00	0.00000	0.03	0.00
Solariella varicosa	0.00042	0.00	0.00000	0.43	0.00
Lischkeia cidaris	0.00007	0.00	0.00000	0.03	0.00
Epitonium groenlandicum	0.00010	0.00	0.00000	0.06	0.00
Balcis spp.	0.00044	0.00	0.00000	0.19	0.00
Crepidula nummaria	0.00020	0.00	0.00000	0.13	0.00

TABLE VI.A.XI

CONTINUED

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Phylum Count	% Phylum wt
Trichotropis cancellata	0.00007	0.00	0.00000	0.03	0.00
Natica clausa	0.00030	0.02	0.00044	1.37	0.26
Polinices pallida	0.00015	0.01	0.00034	0.35	0.20
Polinices lewisii	0.00008	0.00	0.00002	0.03	0.01
Fusitriton oregonensis	0.00129	0.68	0.01968	18.79	11.52
Trophonopsis clathratus	0.00004	0.00	0.00001	0.02	0.00
Trophonopsis stuarti	0.00010	0.00	0.00001	0.06	0.01
Trophonopsis pacificus	0.00001	0.00	0.00000	0.01	0.00
Trophonopsis lasius	0.00004	0.00	0.00000	0.04	0.00
Trophonopsis multicostalis	0.00010	0.00	0.00000	0.06	0.00
Nucella lamellosa	0.00848	0.17	0.00492	17.99	2.88
Buccinidae	0.00006	0.00	0.00002	0.08	0.01
Buccinum cnismatum	0.00001	0.00	0.00001	0.01	0.00
Buccinum glaciale	0.00010	0.00	0.00005	0.06	0.03
Buccinum plectrum	0.00061	0.05	0.00144	2.45	0.84
Beringius kennicotti	0.00016	0.01	0.00029	0.24	0.17
Colus spp.	0.00009	0.00	0.00002	0.07	0.01
Colus herendeenii	0.00008	0.00	0.00002	0.04	0.01
Colus halli	0.00004	0.00	0.00001	0.04	0.01
Neptunea lyrata	0.00151	3.83	0.11155	33.80	65.31
Plicifusus kroyeri	0.00003	0.00	0.00002	0.03	0.01
Pyrulofusus harpa	0.00002	0.00	0.00009	0.03	0.05
Volutopsius middendorffi	0.00001	0.00	0.00000	0.01	0.00
Arctomelon stearnsii	0.00005	0.01	0.00031	0.04	0.18
Volutomitra alaskana	0.00001	0.00	0.00001	0.01	0.01
Admete couthouyi	0.00006	0.00	0.00001	0.09	0.00
Suavodrillia kennicottii	0.00001	0.00	0.00000	0.01	0.00
Oenopota decussata	0.00004	0.00	0.00000	0.04	0.00
Propebela	0.00013	0.00	0.00000	0.06	0.00
Gastropteron pacificum	0.00056	0.00	0.00000	0.13	0.00
Dorididae	0.00011	0.00	0.00009	0.24	0.05

TABLE VI.A.XI

CONTINUED

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Phylum Count	% Phylum wt
Triopha spp.	0.00005	0.00	0.00000	0.02	0.00
Triopha aurantica	0.00010	0.00	0.00002	0.13	0.01
Dendronotidae	0.00045	0.00	0.00002	0.77	0.01
Tritonia spp.	0.00254	0.00	0.00000	0.57	0.00
Tritonia exsulans	0.00006	0.00	0.00014	0.04	0.08
Aeolidia papillosa	0.00012	0.00	0.00003	0.10	0.02
Dentalium spp.	0.00007	0.00	0.00000	0.03	0.00
Cephalopoda	0.00014	0.00	0.00005	0.10	0.03
Nymphon grossipes	0.01240	0.00	0.00000	95.31	38.30
Pycnogonidae	0.00010	0.00	0.00000	4.69	61.70
Cyclopoida	-	-	-	-	-
Thoracica	0.00151	0.09	0.00261	0.07	0.12
Balanus spp.	0.00007	0.01	0.00037	0.02	0.02
Balanus balanus	0.00586	0.16	0.00452	0.51	0.21
Balanus evermani	0.00014	0.02	0.00062	0.01	0.03
Balanus hesperius	0.00008	0.00	0.00007	0.01	0.00
Balanus hoekianus	0.00001	0.00	0.00000	0.00	0.00
Balanus rostratus	0.00085	0.05	0.00138	0.08	0.06
Mysidacea	0.00007	0.00	0.00000	0.00	0.00
Acanthomysis dybowskii	0.00066	0.00	0.00000	0.01	0.00
Diastylis bidentata	0.00001	0.00	0.00000	0.00	0.00
Rocinela spp.	0.00085	0.00	0.00000	0.01	0.00
Rocinela augustata	0.00007	0.00	0.00000	0.00	0.00
Amphipoda	0.00083	0.00	0.00003	0.06	0.00
Ampelisca macrocephala	0.00111	0.00	0.00001	0.06	0.00
Ampeliscidae birulai	0.00009	0.00	0.00000	0.01	0.00
Ampeliscida eschrichti	0.00197	0.00	0.00000	0.02	0.00
Bylilis gaimandi	0.00004	0.00	0.00000	0.00	0.00
Erichthonius spp.	0.00004	0.00	0.00000	0.00	0.00
Erichthonius tolli	0.00006	0.00	0.00000	0.00	0.00
Rhachotropis oculata	0.00004	0.00	0.00000	0.00	0.00
Gammaridae	0.00085	0.00	0.00001	0.01	0.00
Anonyx spp.	0.00035	0.00	0.00001	0.02	0.00
Anonyx nugax	0.00155	0.00	0.00002	0.09	0.00
Lepidepecreum comatum	0.00004	0.00	0.00000	0.00	0.00
Monoculodes zernovi	0.00004	0.00	0.00000	0.00	0.00
Pardalisca cuspidata	0.00007	0.00	0.00000	0.00	0.00

TABLE VI.A.XI

CONTINUED

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Phylum Count	% Phylum wt
Heterophoxus scalatus	0.00004	0.00	0.00000	0.00	0.00
Stegocephalus inflatus	0.00564	0.00	0.00001	0.05	0.00
Caprellidae	0.00008	0.00	0.00000	0.00	0.00
Decapoda	0.02818	0.00	0.00006	0.25	0.00
Pandalus spp.	0.00472	0.04	0.00114	0.55	0.05
Pandalus borealis	0.01413	0.84	0.02439	6.59	1.13
Pandalus goniurus	0.11422	20.72	0.60282	48.26	27.97
Pandalus platyceros	0.02316	0.09	0.00269	0.57	0.12
Pandalus hypsinotus	0.00461	0.22	0.00642	1.25	0.30
Pandalus danae	0.00004	0.00	0.00000	0.00	0.00
Pandalopsis dispar	0.00068	0.03	0.00096	0.07	0.04
Hyppolytidae	0.00068	0.02	0.00046	0.18	0.02
Spirontocaris lamellicornis	0.00047	0.00	0.00003	0.02	0.00
Spirontocaris spina	0.00254	0.00	0.00000	0.02	0.00
Lebbeus groenlandica	0.00007	0.00	0.00008	0.02	0.00
Eualus spp.	0.00001	0.00	0.00000	0.00	0.00
Eualus barbata	0.00034	0.00	0.00001	0.01	0.00
Eualus suckleyi	0.00117	0.00	0.00002	0.04	0.00
Eualus townsendi	0.00035	0.00	0.00008	0.02	0.00
Eualus avina	0.03917	0.00	0.00005	0.34	0.00
Heptacarpus spp.	0.00028	0.00	0.00000	0.00	0.00
Crangonidae	0.01640	0.13	0.00391	3.02	0.18
Crangon spp.	0.01744	0.37	0.01070	4.70	0.50
Crangon dalli	0.01028	0.78	0.02275	9.04	1.06
Crangon franciscorum	0.00010	0.00	0.00002	0.00	0.00
Crangon communis	0.06411	0.26	0.00743	8.77	0.34
Crangon resima	0.00023	0.00	0.00001	0.01	0.00
Sclerocrangon spp.	0.00477	0.10	0.00277	0.55	0.13
Sclerocrangon boreas	0.00031	0.00	0.00009	0.01	0.00
Argis spp.	0.00162	0.11	0.00334	0.78	0.15
Argis dentata	0.00116	0.04	0.00104	0.31	0.05
Argis crassa	0.00007	0.00	0.00005	0.01	0.00
Paguridae	0.00184	0.07	0.00200	0.22	0.09
Pagurus spp.	0.00027	0.01	0.00044	0.02	0.02
Pagurus ochotensis	0.00106	0.64	0.01869	0.65	0.87

TABLE VI.A.XI

CONTINUED

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Phylum Count	% Phylum wt
Pagurus aleuticus	0.00057	0.05	0.00138	0.09	0.06
Pagurus capillatus	0.00049	0.20	0.00570	0.29	0.26
Pagurus kennerlyi	0.00037	0.01	0.00027	0.04	0.01
Pagurus beringanus	0.00007	0.00	0.00005	0.01	0.00
Pagurus confragosus	0.00013	0.01	0.00041	0.01	0.02
Pagurus trigonocheirus	0.00007	0.00	0.00000	0.00	0.00
Elassochirus spp.	0.00012	0.00	0.00009	0.00	0.00
Elassochirus tenuimanus	0.00063	0.09	0.00274	0.17	0.13
Elasschirus cavimanus	0.00005	0.00	0.00003	0.00	0.00
Elassochirus gilli	0.00010	0.00	0.00003	0.00	0.00
Labidochirus spp.	0.00986	0.01	0.00037	0.09	0.02
Labodochirus spendescens	0.00079	0.01	0.00028	0.09	0.01
Lithodidae	0.00028	0.00	0.00002	0.00	0.00
Paralithodes camtschatica	0.00038	7.20	0.20953	0.18	9.72
Rhinolithodes wosnessenskii	0.00010	0.01	0.00015	0.00	0.01
Oregonia gracilis	0.00234	0.23	0.00677	0.90	0.31
Hyas lyratus	0.00303	1.61	0.04691	1.60	2.18
Chionoecetes bairdi	0.00941	38.60	1.12292	9.05	52.11
Chorilia longipes	0.00002	0.00	0.00001	0.00	0.00
Cancridae	0.00007	0.00	0.00002	0.00	0.00
Cancer magister	0.00051	1.21	0.03506	0.09	1.63
Cancer oregonensis	0.00016	0.01	0.00020	0.03	0.01
Pinnixa occidentalis	0.00003	0.00	0.00000	0.00	0.00
Ectoprocta	0.00007	0.00	0.00011	42.00	6.83
Membranipora spp.	0.00004	0.00	0.00000	5.31	0.12
Alcyonidium spp.	0.00011	0.04	0.00104	30.82	65.49
Flustrellidae	0.00009	0.00	0.00004	9.11	2.48
Flustrella spp.	0.00004	0.01	0.00040	12.75	25.08
Brachiopoda	0.00106	0.02	0.00061	79.27	84.33
Terebratulina unguicula	0.00007	0.00	0.00000	0.97	0.16
Laqueus californianus	0.00016	0.00	0.00006	12.03	8.22
Terebratalia spp.	0.00028	0.00	0.00000	1.93	0.32
Terebratalia	0.00012	0.00	0.00005	5.80	6.97

TABLE VI.A.XI

CONTINUED

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Phylum Count	% Phylum wt
Ceramaster patagonicus	0.00005	0.01	0.00021	0.11	0.04
Ceramaster stellatus	0.00002	0.00	0.00003	0.03	0.01
Luidia foliolata	0.00010	0.00	0.00002	0.12	0.00
Ctenodiscus crispatus	0.00113	0.01	0.00019	3.04	0.04
Echinasteridae	0.00009	0.00	0.00003	0.07	0.01
Henricia spp.	0.00019	0.01	0.00038	0.76	0.08
Pteraster spp.	0.00028	0.02	0.00052	0.07	0.10
Pteraster tesselatus	0.00006	0.01	0.00015	0.04	0.03
Solasteridae	0.00002	0.00	0.00001	0.01	0.00
Crossaster borealis	0.00010	0.02	0.00051	0.07	0.10
Crossaster papposus	0.00011	0.01	0.00030	0.48	0.06
Solaster dawsoni	0.00011	0.05	0.00141	0.18	0.28
Solaster stimpsoni	0.00029	0.00	0.00003	0.11	0.01
Asteridae	0.00016	0.04	0.00127	0.38	0.25
Asterias spp.	0.00004	0.01	0.00018	0.02	0.04
Evasterias spp.	0.00020	0.46	0.01333	1.16	2.64
Evasterias echinosoma	0.00010	0.02	0.00062	0.04	0.12
Evasterias troschelii	0.00030	1.40	0.04085	1.77	8.10
Leptasterias spp.	0.00015	0.17	0.00491	1.10	0.97
Leptasterias polaris	0.00025	0.21	0.00611	2.05	1.21
Lethasterias spp.	0.00004	0.00	0.00009	0.03	0.02
Lethasterias nanimemsis	0.00017	0.17	0.00488	0.83	0.97
Echinarachnius parma	0.00326	0.70	0.02044	28.21	4.05
Strongylocentrotidae	0.00013	0.02	0.00045	0.20	0.09
Strongylocentrotus droebachiensis	0.00347	2.29	0.06673	33.69	13.23
Strongylocentrotus franciscanus	0.00001	0.00	0.00012	0.01	0.02
Amphipholis pugetana	0.00007	0.00	0.00000	0.04	0.00
Gorgonocephalidae	0.00010	0.00	0.00003	0.07	0.01
Gorgonocephalus caryi	0.00006	0.01	0.00016	0.14	0.03

TABLE VI.A.XI

CONTINUED

Taxonomic Name	Count per m^2	% of Weight	Grams per m^2	% Phylum Count	% Phylum wt
Ophiopholis aculeata	0.00008	0.00	0.00000	0.09	0.00
Ophiuridae	0.00012	0.00	0.00001	0.21	0.00
Ophiopenia spp.	0.00001	0.00	0.00000	0.01	0.00
Ophiopenia disacantha	0.00016	0.00	0.00000	0.19	0.00
Ophiopenia tetracantha	0.00004	0.00	0.00000	0.02	0.00
Ophiura sarsi	0.00142	0.00	0.00006	2.90	0.01
Holothuroidea	0.00044	0.01	0.00032	0.25	0.06
Synaptidae	0.00007	0.00	0.00000	0.04	0.00
Molpadiidae	0.00001	0.00	0.00001	0.01	0.00
Cucumariidae	0.00224	6.84	0.19888	9.58	39.44
Cucumaria fallax	0.00151	4.85	0.14102	11.88	27.96
Urochordata	0.00016	0.01	0.00035	29.72	41.33
Synoicidae	0.00676	0.02	0.00049	68.84	58.53
Styelidae	0.00007	0.00	0.00000	1.43	0.14

Cluster Analysis for Grab samples

Cluster analysis of benthic grab samples using untransformed (Fig. VI.A.1) and natural logarithm (*ln*) transformed abundance data (Fig. VI.A.2) revealed the presence of two major station groups. The station groups formed by each analysis were identical except for two stations. Station 31, classified as a member of Station Group 1 by a cluster analysis of *ln* transformed abundance data (Fig. VI.A.2), was classified as a member of Station Group 2 by a cluster analysis of untransformed data (Fig. VI.A.1). Station 8 also classified as a member of Station Group 1 using *ln* transformed abundance data (Fig. VI.A.2) did not join any station group when untransformed data was used (Fig. VI.A.1). Station Group 1 consisted of stations located in southwestern Cook Inlet and Station 40 near the entrance to Kachemak Bay (Fig. VI.A.3). Station Group 2 consisted of stations in the eastern part of Cook Inlet adjacent to Kachemak Bay.

An inverse cluster analysis, examining the similarities between species indicated the presence of 39 species groups (Fig. VI.A.4; Table VI.A.XII). A two-way coincidence table was constructed comparing the station groups and species groups formed by a cluster analysis of *ln* transformed abundance data (Table VI.A.XIII). Stations in Station Group 1 were characterized by the presence of species in Species Group 20 (Table VI.A.XIII). An examination of the two-way table (Table VI.A.XIII) also indicated the presence of subgroups within Station Group 1 characterized by the presence of species in Species Groups 1, 15 and 16 (Table VI.A.XIII). Station Group 2 was characterized by the presence of species in Species Group 35 and the low diversity and species richness of its fauna (Table VI.A.XIV). Station 31 which was classified as a member of Station Group 2 by a cluster analysis of untransformed abundance data was characterized by the presence of species from both Species Groups 20 and 35 (Table VI.A.XIV) and thus, appeared to be transitional in terms of its fauna between that of stations in Station Groups 1 and 2.

Biomass and Species Diversity for Grab Samples

The invertebrates taken by van Veen grab at 18 stations included 99 species. Three of the five highest values for formalin wet weights occurred in the central region of the Inlet (Fig. IV.1) with values of 731, 241, and 128 g per m^2 at Stations 45, 31, and 33 respectively. In outer Kachemak Bay, 558 g per m^2 was observed at Station 42. In the outer region of the Inlet (Fig. IV.1) 163 g per m^2 were observed for Station 6. Table VI.A.XV ranks stations in terms of weights and species diversity of invertebrates taken by grab. Three of the five highest values for species diversity were calculated for outer region Station (Fig. IV.1) 8, 7 and 5 (Table VI.A.XV). High values for species diversity were also observed at Stations 31 and 45 (Table VI.A.XV) in the central zone of the Inlet (Fig. IV.1). Table VI.A.XVI provides a taxon list for the organisms taken by grab and information on their relative abundance. Data for individual stations is available from the Alaska Environmental Data Center.

TABLE VI.A.XII. SPECIES GROUPS FORMED BY AN INVERSE CLUSTER ANALYSIS OF NATURAL LOGARITHM TRANSFORMED ABUNDANCE DATA

```
SPECIFS GROUP  1
               CARDIOMYA PLANETICA
               HAPLOOPS TUBICOLA
               LAONICE CIRRATA
               MITRELLA GOULDI
               TRAVISIA FORBESII
               AMPELISCIDA ESCHRICHTI
               PARVILUCINA TENUISCULPTA
               LEUCON NASICA
               ANONYX NUGAX
               SPIOCHAETOPTERUS COSTARUM
               OPHIOPENIA DISACANTHA
               NINOE GEMMEA
               ARICIDEA SP.
               ODONTOGENA BOREALIS
               HETEROPHOXUS OCULATUS
               PARAONIS GRACILIS

SPECIFS GROUP  2
               ANCISTROSYLLIS SP.
               DENTALIUM SP.
               AMPHARETF SP.
               NATICA CIAUSA

SPECIFS GROUP  3
               EULALIA SP.
               AMPELISCIDA FURCIGERA
               NUCULANA SP.
               SCOLOPOLOS SP.
               TRAVISIA SP.
               PINNIXIA SCHMITTI
               ASTARTE ESQUIMAULTI
               PHOTIS SP.

SPECIFS GROUP  4
               SYLLIS SP.

SPECIFS GROUP  5
               PRIONOSPIA SP.

SPECIFS GROUP  6
               NEPHTYS ASSIMILIS
               ASYCHIS SIMILIS
               POLYDORA SOCIALIS
               POLYNOE CANADENSIS
               ORCHOMENE SP.
               PISTA SP.

SPECIFS GROUP  7
               LUMBRINERIS LATREILLI
               ISCHYROCERUS SP.
               NEPHTYS CORNUTA
               LUMBRINERIS SIMILABRIS
               MALDANE SARSI
               RHODINE SP.
               PHASCOLION STROMBI
               DIASTYLIS ALASKENSIS

SPECIFS GROUP  8
               MELINNA ELISABETHAE
               METOPA SP.

SPECIFS GROUP  9
               NEPHTYS CAECA
               ASTARTE ROLLANDI

SPECIFS GROUP 10
               GAMMARELLUS SP.
               ANONYX SP.
               BYBLIS SP.

SPECIFS GROUP 11
               NEVERITA NANA

SPECIFS GROUP 12
               AXIOTHELLA SP.
               AXICTHELLA CATENATA

SPECIFS GROUP 13
               CHAETOZONE SETOSA
               STERNASPIS SCUTATA

SPECIFS GROUP 14
               THYASIRA FLEXUOSA

SPECIFS GROUP 15
               NEREIS PROCERA
               POLINICES PALLIDA
               HAPLOSCOLOPLOS PANAMENSIS
               YOLDIA AMYGDALEA
               GLYCINDE ARMIGERA
               NUCULANA FOSSA
               OENOPOTA SP.
               CHONE SP.

SPECIFS GROUP 16
               MAGELONA SP.
               MYRIOCHELE SP.
               SCOLOPLOS ARMIGER

SPECIFS GROUP 17
               SERRIPES GROENLANDICUS
               RETUSA OBTUSA

SPECIFS GROUP 18
               RETUSA SP.
               BALANUS CRENATUS
               MEGALONA
               NEREIS SP.
               NEPTUNEA LYRATA
               AMPHARETE VEGA
               LAONOME KROYERI

SPECIFS GROUP 19
               LUMBRINERIS MINIMA
               ARICIDEA JEFFREYSII
               AXIOTHELLA RUBROCINCTA
               CHONE GRACILIS
               LUMBRINERIS LUTI

SPECIFS GROUP 20
               PISTA CRISTATA
               PSEPHIDIA LORDI
               GONIADA MACULATA
               GLYCERA CAPITATA
               OWENIA FUSIFORMIS
               MAGELONA JAPONICA
               NUCULANA PERNULA
               MACOMA MOESTA ALASKANA
               CAPITELLA CAPITATA
               SOLARIELLA OBSCURA
               SOLARIELLA VARICOSA
               MACOMA SP.
               ETEONE LONGA
               NEPHTYS PUNCTATA
               PRAXILLELLA AFFINIS
               LYSIPPE LABIATA
               PROTOMEDIA SP.
               NEPHTYS CILIATA
               THARYX SP.
               PRIONOSPIO MALMGRENI
               PRAXILLELLA PRAETERMISSA
               MYRIOCHELE HEERI
               GLYCINDE PICTA
               PRAXILLELLA GRACILIS
               SCALIBREGMA INFLATUM
               LUMBRINERIS SP.
               NUCULA TENUIS
               AXINOPSIDA SERRICATA
               MACOMA CALCAREA
               HAPLOSCOLOPLOS ELONGATUS
               PHOLOE MINUTA
               TEREBELLIDES STROEMII
               NEPHTYS SP.
               EUDORELLA EMARGINATA
               BYBLIS GAIMARDI
               AMPELISCA MACROCEPHALA
               NEPHTYS LONGASETOSA
               NEPHTYS RICKETTSI
               EUDORELLA PACIFICA
               LUMBRINERIS ZONATA

SPECIFS GROUP 21
               LORA SP.
               ODOSTOMIA SP.
               EUDORELLOPSIS INTEGRA
               SPHAERODOROPSIS SPHAERULIFER
               PAGURUS SP.

SPECIFS GROUP 22
               MALDANE GLEBIFEX
               CHONE INFUNDIBULIFORMIS
               ARTACAMA CONIFERI
               ANAITIDES MACULATA

SPECIFS GROUP 23
               RHODINE GRACILIOR
               POLYCIRRUS SP.

SPECIFS GROUP 24
               CHIONOECETES BAIRDI

SPECIFS GROUP 25
               NEREIS PELAGICA
               PONTOCRATES ARENARIUS

SPECIFS GROUP 26
               SPIOPHANES CIRRATA
               LORA SOLIDA
               OENOPOTA TURRICULA

SPECIFS GROUP 27
               CHAETODERMA ROBUSTA
               DIAMPHIODIA CRATERODMETA
               AMPHARETE ARCTICA
               YOLDIA SP.

SPECIFS GROUP 28
               MYSELLA TUMIDA
               OPHIURA SARSI
               POLINICES SP.
               UNIOPLUS MACRASPIS
               MELINNA CRISTATA
               ONUPHIS IRIDESCENS
               YOLDIA SCISSURATA

SPECIFS GROUP 29
               YOLDIA HYPERBOREA
               CUCUMARIA CALCIGERA
               CYLICHNA ALBA
               DENTALIUM DALLI
               TRAVISIA BREVIS
               NOTOMASTUS SP.

SPECIFS GROUP 30
               LUMBRINERIS BICIRRATA
               COSSURA LONGOCIRRATA
               MUSCULUS NIGER

SPECIFS GROUP 31
               MYA SP.
               BALANUS SP.
               ACILA CASTRENIS
               BALANUS BALANOIDES
               PROTOTHACA STAMINEA
               SPISULA POLYNYMA

SPECIFS GROUP 32
               ISCHNOCHITON ALBUS
               ASTARTE BOREALIS
               HARMOTHOE IMBRICATA
               CYCLOCARDIA CREBRICOSTATA
               TEREBRATULINA UNGUICULA

SPECIFS GROUP 33
               TYPOSYLLIS SP.

SPECIFS GROUP 34
               SPIOPHANES SP.
               OLIVELLA BAETICA

SPECIFS GROUP 35
               OPHELIA LIMACINA
               ECHINARACHNIUS PARMA
               SPIOPHANES BOMBYX
               GLYCYMERIS SUBOBSOLETA
               PARAPHOXUS SP.
               TELLINA NUCLEOIDES

SPECIFS GROUP 36
               AMMODYTES HEXAPTERUS

SPECIFS GROUP 37
               CYCLOCARDIA VENTRICOSA
               OLIVELLA BIPLICATA
               ANASPIO BOREUS
               SPIO FILICORNIS
               POLYDORA SP.
               PARAPHOXUS OBTUSIDENS

SPECIFS GROUP 38
               PANDORA FILOSA
               ISCHYROCERUS ANGUIPES

SPECIFS GROUP 39
               PTILOSARCUS GURNEYI
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[illegible]

TABLE VI.A.XIV

BIOMASS, DIVERSITY AND ABUNDANCE OF STATIONS IN STATION GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED ABUNDANCE DATA

	Wet wt g per m^2	Abundance No. per m^2	No. of Species	Shannon		Brillouin		Species Richness
				Diversity	Evenness	Diversity	Evenness	
Station Group 1*								
6	98	2136	74	2.43	.56	2.36	.56	9.52
18	24	1814	79	3.24	.74	3.13	.74	10.84
27	15	1600	71	3.00	.70	2.92	.70	9.48
33	77	2050	88	3.28	.73	3.20	.73	11.41
40	30	3432	59	2.07	.50	2.63	.50	7.12
54	27	1372	83	3.09	.70	2.99	.70	11.35
5	19	1670	92	3.42	.75	3.32	.75	12.26
7	11	1158	99	3.57	.77	3.42	.77	13.89
8**	9	446	84	3.77	.85	3.50	.85	13.60
18	30	1814	98	3.34	.73	3.24	.72	12.92
28	11	930	54	3.05	.76	2.95	.76	7.75
40	48	3988	83	2.03	.46	2.00	.45	9.89
1	57	2442	86	3.37	.75	3.30	.75	10.89
7	26	1368	62	2.88	.69	2.80	.69	8.45
31†	120	406	49	3.39	.87	3.18	.87	7.99
Station Group 2								
42	279	822	33	1.84	.52	1.77	.52	4.77
45	366	532	53	3.37	.84	3.20	.84	8.28
46	20	150	17	2.63	.93	2.44	.92	3.19
42	103	1332	35	1.00	.28	.96	.27	4.72
4	14	486	39	2.12	.58	2.00	.57	6.14
40A	12	376	34	2.92	.83	2.77	.82	5.56

* See Fig. IV.1

**Did not join any station groups in an analysis using *ln* transformed abundance data

† Joined Station Group 2 when *ln* transformed data was used

TABLE VI.A.XV

A COMPARISON OF MEAN TOTAL GRAMS (FORMALIN WET WEIGHT) OF INVERTEBRATES IN GRAB SAMPLES AND SPECIES DIVERSITY AT DIFFERENT STATIONS IN LOWER COOK INLET

Station	Total g per m^2	Area*	Station	Shannon Diversity Index	Area*
45	731	Central zone	8	3.7	Outer region
42	558	Outer Kachemak	7	3.6	Outer region
31	241	Central zone	31	3.4	Central zone
6	163	Outer region	5	3.4	Outer region
33	128	Central zone	45	3.4	Central zone
PMEL 1	113	Lower Kamishak	PMEL 1	3.3	Lower Kamishak
46	98	Central zone	33	3.3	Central zone
40	74	Mid-Kachemak	18	3.2	Lower Kamishak
PMEL 7	52	Mid-Kachemak	54	3.1	Upper Kamishak
18	48	Lower Kamishak	27	3.0	Lower Kamishak
5	39	Outer region	28	3.0	Lower Kamishak
54	38	Upper Kamishak	PMEL 7	2.8	Mid-Kachemak
PMEL 4	28	Central zone	40A	2.7	Mid-Kachemak
40A	24	Mid-Kachemak	46	2.5	Central zone
27	23	Lower Kamishak	6	2.4	Outer region
28	21	Lower Kamishak	PMEL 4	2.1	Central zone
7	22	Outer region	40	2.0	Mid-Kachemak
8	22	Outer region	42	1.8	Outer Kachemak
Mean	134		Mean	2.9	

*See Fig. IV.1

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TABLE VI.A.XVI

A TAXON LIST FOR ORGANISMS TAKEN BY GRAB AT 18 LOWER COOK INLET STATIONS

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Sarcodina rhizopodea						3
Hydrozoa						6
Abietinaria sp.						1
Anthozoa						1
Alcyonacea nephtheidae			X		X	1
Ptilosarcus gurneyi			X		X	2
Ptilosarcus gurneyi frags.						1
Rhynchocoela	X					13
Rhynchocoela frags.	X				X	11
Nematoda				X		9
Nematoda frags.						1
Polychaeta	X			X	X	17
Polychaeta frags.	X					11
Polynoidae						2
Antinoella sarsi						1
Halosydna brevisetosa						1
Harmothoe imbricata						2
Harmothoe multisetosa						1
Polynoe canadensis						3
Pholoe minuta						16
Euphrosinidae						1
Phyllodocidae						3
Anaitides sp.						1
Anaitides maculata						2
Eteone sp.						1
Eteone longa	X			X		18
Eulalia sp.						1
Ancistrosyllis sp.			X		X	4
Syllidae						4
Autolytus sp.						3
Syllis sp.						3

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Typosyllis sp.						4
Typosyllis alternata						1
Brania sp.						1
Langerhansia cornuta						1
Nereis sp.						2
Nereis pelagica						3
Nereis procera						4
Nereis zonata						7
Nephtyidae						1
Nephtys sp.	X				X	13
Nephtys sp. frags.						5
Nephtys assimilis					X	2
Nephtys ciliata	X		X		X	12
Nephtys caeca						6
Nephtys cornuta						6
Nephtys punctata					X	8
Nephtys rickettsi					X	8
Nephtys longasetosa	X		X	X	X	15
Sphaerodoropsis minuta						1
Sphaerodoropsis sphaerulifer						1
Glyceridae						1
Glycera sp. frags.						1
Glycera capitata	X			X		13
Goniadidae						2
Glycinde picta	X					12
Glycinde armigera						9
Goniada annulata						1
Goniada maculata						10
Onuphis sp.						3
Onuphis sp. frags.						1

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Onuphis conchylega						1
Onuphis geophiliformis						1
Onuphis iridescens						3
Eunicidae						2
Lumbrineridae						1
Lumbrineris sp.	X	X		X		16
Lumbrineris sp. frags.						3
Lumbrineris bicirrata						2
Lumbrineris latreilli						5
Lumbrineris similabris						4
Lumbrineris zonata		X		X	X	8
Lumbrineris luti				X		4
Lumbrineris minima						2
Ninoe gemmea						4
Drilonereis falcata minor						1
Megalomma sp.				X		2
Haploscoloplos panamensis						4
Haploscoloplos elongatus	X	X		X		18
Nainereis sp.						1
Nainereis dendritica						1
Scoloplos sp.						2
Scoloplos armiger				X		6
Paraonidae						3
Aedicira sp.						1
Aricidea sp.						5
Aricidea suecica						1
Aricidea longicornuta						1
Aricidea jeffreysii						3
Paraonis gracilis						9
Apistobranchus tullbergi						1
Spionidae						3

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Anaspio boreus						4
Laonice cirrata					X	2
Polydora sp.						2
Polydora socialis						2
Polydora caulleryi						1
Prionospia sp.						3
Prionospio malmgreni	X			X		13
Prionospio cirrifera						1
Scolecolepides sp.						1
Spio filicornis						5
Boccardia sp.						1
Spiophanes sp.						3
Spiophanes bombyx		X		X		7
Spiophanes cirrata						2
Magelomma sp.	X	X		X	X	11
Magelomma japonica		X		X		7
Spiochaetopterus sp.						1
Spiochaetopterus costarum						2
Spiochaetopterus costarum frags.						1
Cirratulidae						4
Tharyx sp.						14
Chaetozone setosa				X		8
Scalibregma inflatum	X					11
Scalibregma inflatum frags.						1
Ophelia limacina				X		6
Travisia sp.						2
Travisia brevis			X			5
Travisia forbesii						2
Sternaspis scutata						7
Capitellidae		X		X		6
Capitellidae frags.						1

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Capitella capitata						5
Heteromastus filiformis						1
Notomastus sp.						4
Maldanidae						9
Maldanidae frags.						10
Asychis sp. frags.						3
Asychis similis						2
Maldane sarsi				X	X	2
Maldane glebifex						3
Nicomache sp.					X	2
Notoproctus sp.						1
Axiothella sp.						1
Axiothella catenata						2
Axiotella rubrocincta						3
Praxillella sp.						2
Praxillella sp. frags.						1
Praxillella gracilis			X	X	X	10
Praxillella praetermissa				X	X	10
Praxillella affinis						6
Rhodine sp.						2
Rhodine sp. frags.						5
Rhodine bitorquata						1
Rhodine gracilior						2
Rhodine gracilior frags.						1
Oweniidae						3
Oweniidae frags.						3
Owenia sp. frags.						1
Owenia fusiformis						5
Myriochele sp.				X		5
Myriochele sp. frags.						2

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Myriochele heeri	X			X	X	12
Myriochele heeri frags.						3
Sabellariidae frags.						1
Idanthyrsus armatus						1
Cistenides brevicoma						1
Cistenides hyperborea						1
Ampharetidae						3
Ampharete sp.						3
Ampharete arctica						6
Ampharete vega						2
Amphicteis gunneri						1
Lysippe labiata				X		9
Melinna cristata						3
Melina elisabethae						3
Terebellidae						2
Terebellidae frags.						1
Pista sp.						2
Pista cristata				X		9
Polycirrus sp.						2
Artecama sp.						1
Artecama coniferi						3
Artacama proboscidea						1
Lanassa sp.						1
Lanassa nordenskioldi						1
Lanassa venusta						1
Proclea emmi						1
Trichobranchidae						4
Terebellides stroemii	X				X	13
Sabellidae						6
Chone sp.						8

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Chone gracilis						4
Chone infundibuliformis						2
Chone cincta						1
Euchone analis						1
Fabricia sp.						1
Laonome sp.						1
Laonome kroyeri						2
Chitinopoma groenlandica						1
Serpula vermicularis						1
Cossura longocirrata						3
Disoma multisetosum						1
Oligochaeta						1
Mollusca				X		4
Chaetoderma robusta						3
Ischnochiton albus						1
Pelecypoda						9
Acila castrenis						1
Nucula tenuis	X	X		X		15
Nuculana sp.						2
Nuculana pernula		X	X	X	X	8
Nuculana fossa						8
Yoldia sp.						4
Yoldia amygdalea						4
Yoldia hyperborea						3
Yoldia scissurata						4
Yoldia secunda						1
Glycymeris subobsoleta		X	X	X	X	8
Crenella dessucata						1
Musculus niger						3
Musculus corrugatus						1

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Dacrydium pacificum						2
Astarte sp.						1
Astarte borealis						1
Astarte alaskensis						1
Astarte montagui						1
Astarte polaris						1
Astarte rollandi						2
Astarte esquimalti					X	3
Cyclocardia ventricosa			X		X	4
Cyclocardia crebricostata				X		1
Cyclocardia incisa						1
Cyclocardia crassidens						1
Parvilucina tenuisculpta						2
Axinopsida serricata	X	X	X	X	X	16
Thyasira flexuosa						4
Mysella sp.						1
Mysella tumida						2
Odontogena borealis						4
Serripes groenlandicus			X		X	3
Veneridae						1
Saxidomus gigantea						1
Liocyma fluctuosa						1
Psephidia lordi				X		10
Protothaca staminea						2
Spisula polynyma		X		X		3
Macoma sp.					X	8
Macoma calcarea	X	X	X	X	X	14
Macoma moesta alaskana			X	X	X	6
Tellina nuculoides		X	X	X	X	9
Siliqua alta						1

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Mya sp.						2
Mya elegans						1
Hiatella arctica						1
Pandora filosa						2
Cardiomya sp.						1
Cardiomya pectenata						1
Cardiomya planetica					X	2
Gastropoda						2
Margarites sp.						1
Solariella sp.						1
Solariella obscura	X					11
Solariella varicosa						9
Natica clausa			X		X	2
Polinices sp.						2
Neverita nana						3
Polinices pallida			X		X	6
Neptunea lyrata			X		X	1
Mitrella gouldi						2
Olivella biplicata						2
Olivella baetica						2
Oenopota sp.						7
Oenopota turricula						2
Lora sp.						2
Lora quadra						1
Lora solida						2
Odostomia sp.						2
Turbonilla torquata						1
Retusa sp.						2
Retusa obtusa						2
Gastropteron pacificum						1
Cylichna alba						2

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Scaphopoda						1
Dentalium sp.						2
Dentalium dalli						2
Cadulus sp.						1
Cadulus tolmei						1
Crustacea						1
Podocopa						5
Calanus sp.						1
Balanus sp.						2
Balanus balanoides			X	X	X	1
Balanus crenatus						2
Cumacea						2
Lamprops sp.						1
Lamprops fasciata						1
Leucon nasica						3
Eudorella sp.						1
Eudorella emarginata				X		10
Eudorella pacifica						8
Eudorellopsis integra						3
Diastylis sp.						1
Diastylis alaskensis						3
Campylaspis rubicunda						1
Isopoda						2
Arcturus beringanus						1
Gnorimosphaeroma oregonensis						1
Gnathia sp.						1
Anthuridae						1
Amphipoda				X		9
Ampeliscidae frags.						1

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Ampelisca macrocephala	X	X		X	X	13
Ampelisca eschrichti						2
Byblis sp.						2
Byblis gaimardi	X			X	X	12
Haploops tubicola						2
Ampelisca furcigera						2
Calliopiidae						1
Colomastigidae						1
Richthonius grebniizkii						1
Gammaridae						2
Gammarellus sp.						2
Melita sp.						1
Melita dentata						1
Euhaustorius eous						1
Isaeidae						1
Photis sp.						3
Photis spasskii						1
Protomedia sp.						8
Protomedia epimerata						1
Podoceropsis sp.						1
Ischyrocerus sp.						6
Ischyrocerus anguipes						2
Lysianassidae						1
Lysianassidae frags.						2
Anonyx sp.						4
Anonyx nugax						4
Orchomene sp.						4
Melphidippidae						1
Bathymedon sp.						1
Pontocrates arenarius						3

TABLE VI.A.XVI

CONTINUED

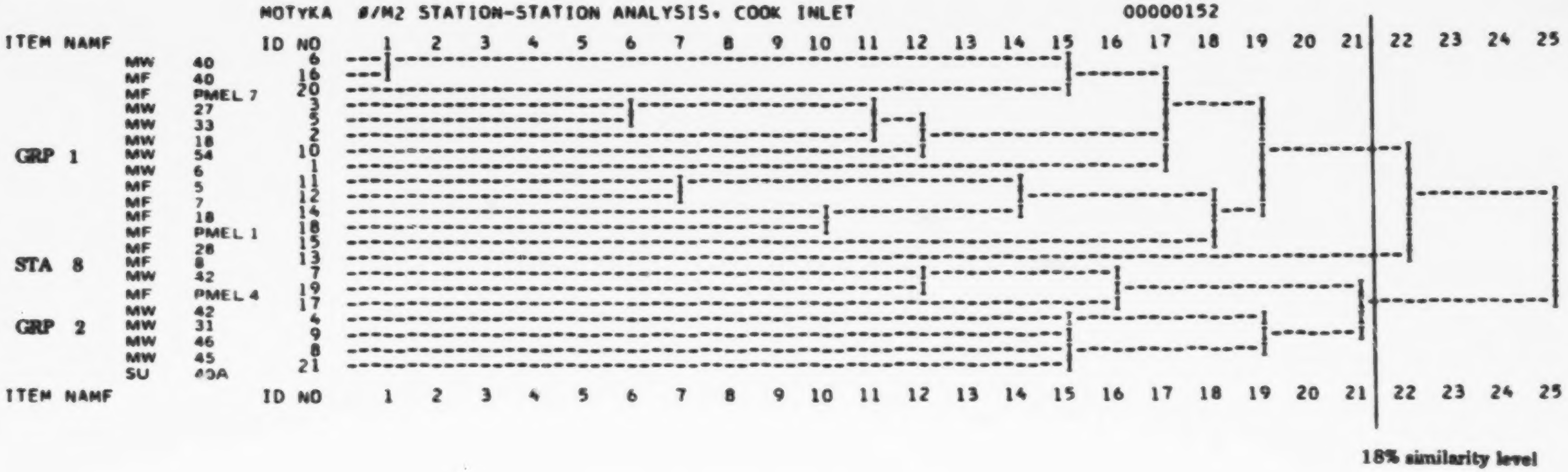
Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Phoxocephalidae						3
Heterophoxus oculatus						4
Paraphoxus sp.				X		5
Paraphoxus obtusidens		X		X		2
Paraphoxus sp.						1
Paraphoxus oculatus						1
Stenothoidae						1
Metopa sp.						4
Paraphoxus robusta						1
Synopiidae						1
Phronimella sp.						1
Caprellidae						1
Euphausiacea						1
Decapoda						3
Decapoda frags.						1
Hippolytidae						1
Eualus sp.						1
Eualus avina						1
Eualus berkeleyorum						1
Crangon sp.						1
Crangon communis						1
Pagurus sp.						5
Pagurus granosimanus						1
Albuneidae						1
Chionoecetes sp.						1
Chionoecetes bairdi						3
Pinnixia schmitti						2
Sipunculida						1
Golfingia sp.						1
Golfingia margaritacea						1
Phascolion strombi						3

TABLE VI.A.XVI

CONTINUED

Taxon Name	Crit 1*	Crit 2*	Crit 3*	Crit 4*	Crit 5*	Sta Occ
Phascolosoma sp.						1
Phoronida						2
Ectoprocta			X	X		6
Lichenopora verrucaria						1
Terebratulina sp.						1
Terebratulina unguicula						2
Terebratulina crossei						1
Laqueus californianus						1
Terebratulina transversa						1
Echinarachnius parma		X	X	X	X	7
Allocentrotus fragilis						1
Strongylocentrotus sp.						1
Ophiuroidea					X	10
Ophiuroidea frags.						2
Diamphiodia craterodmeta				X		5
Unioplus macraspis						2
Ophiuridae						1
Ophiopenia disacantha						3
Ophiura sp.						1
Ophiura sarsi						3
Holothuroidea						1
Cucumaria calcigera					X	3
Ammodytes hexapterus		X	X	X	X	4
Unidentified	X			X		11
Unidentified Frags.						1
Total Number of Taxons						389

*Criteria = 1 taxon occurs in 50 pct or more of stations
2 at least 10 pct of individuals at some station
3 at least 10 pct of wet biomass at some station
4 abundant wrt No. individuals at some station
5 abundant wrt total biomass at some station



MOTYKA #/M2 STATION-STATION ANALYSIS, COOK INLET
00000152
ITEM NAMF
ID NO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
MW 40 6
MF 40 16
MF PMEL 7 20
MW 27 3
MW 33 5
MW 18 2
GRP 1
MW 54 10
MW 6 1
MF 5 11
MF 7 12
MF 18 14
MF PMEL 1 18
MF 28 15
STA 8
MF 8 13
MW 42 7
MF PMEL 4 19
17
MW 42 4
GRP 2
MW 31 9
MW 46 8
MW 45 21
SU 40A
ITEM NAMF
ID NO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
18% similarity level

Figure VI.A.1. Cluster analysis of untransformed abundance data from benthic grab samples in Cook Inlet.

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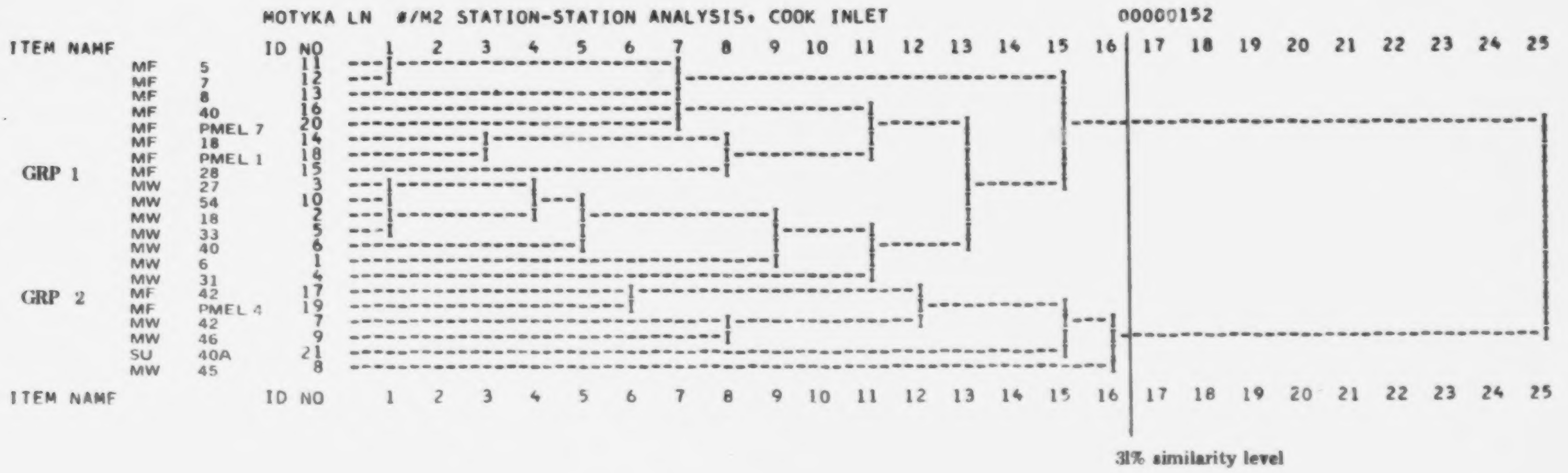
MOTYKA LN #/M2 STATION-STATION ANALYSIS, COOK INLET
00000152
ITEM NAME
ID NO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
GRP 1
GRP 2
MF 5 11
MF 7 12
MF 8 13
MF 40 16
MF PMEL 7 20
MF 18 14
MF PMEL 1 18
MF 28 15
MW 27 3
MW 54 10
MW 18 2
MW 33 5
MW 40 6
MW 6 1
MW 31 4
MF 42 17
MF PMEL 4 19
MW 42 7
MW 46 9
SU 40A 21
MW 45 8
31% similarity level

Figure VI.A.2. Cluster analysis of natural logarithm transformed abundance data from benthic grab samples in Cook Inlet.

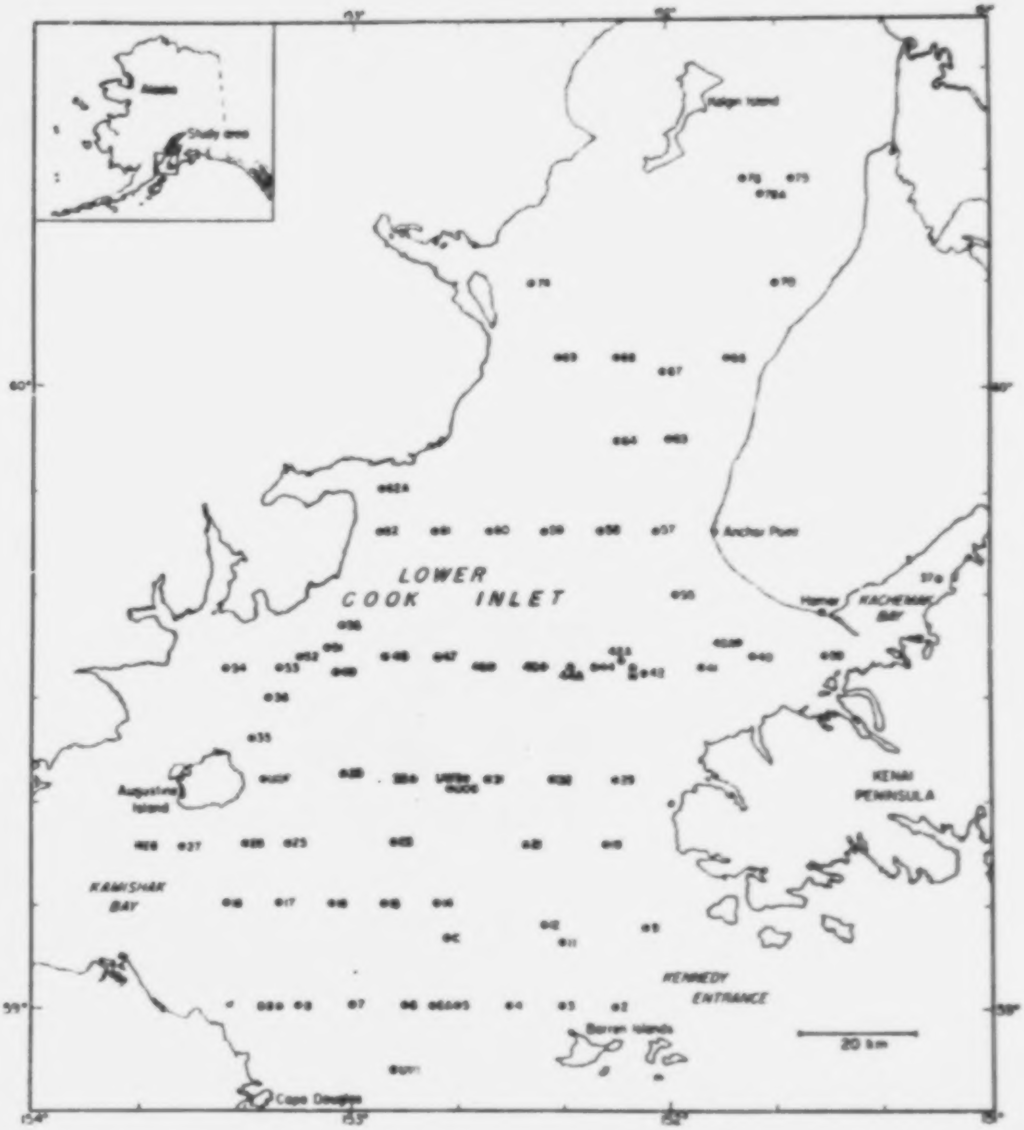
153°
152°
151°
60°
59°
154°
Alaska
Study area
Kalgin Island
Anchor Point
LOWER
COOK INLET
Homer
KACHEMAK BAY
KENAI PENINSULA
Augustine Island
KAMISHAK BAY
KENNEDY ENTRANCE
Barren Islands
20 km
Cape Douglas

Figure VI.A.3. Location of stations in station groups delineated by a cluster analysis of benthic grab data.

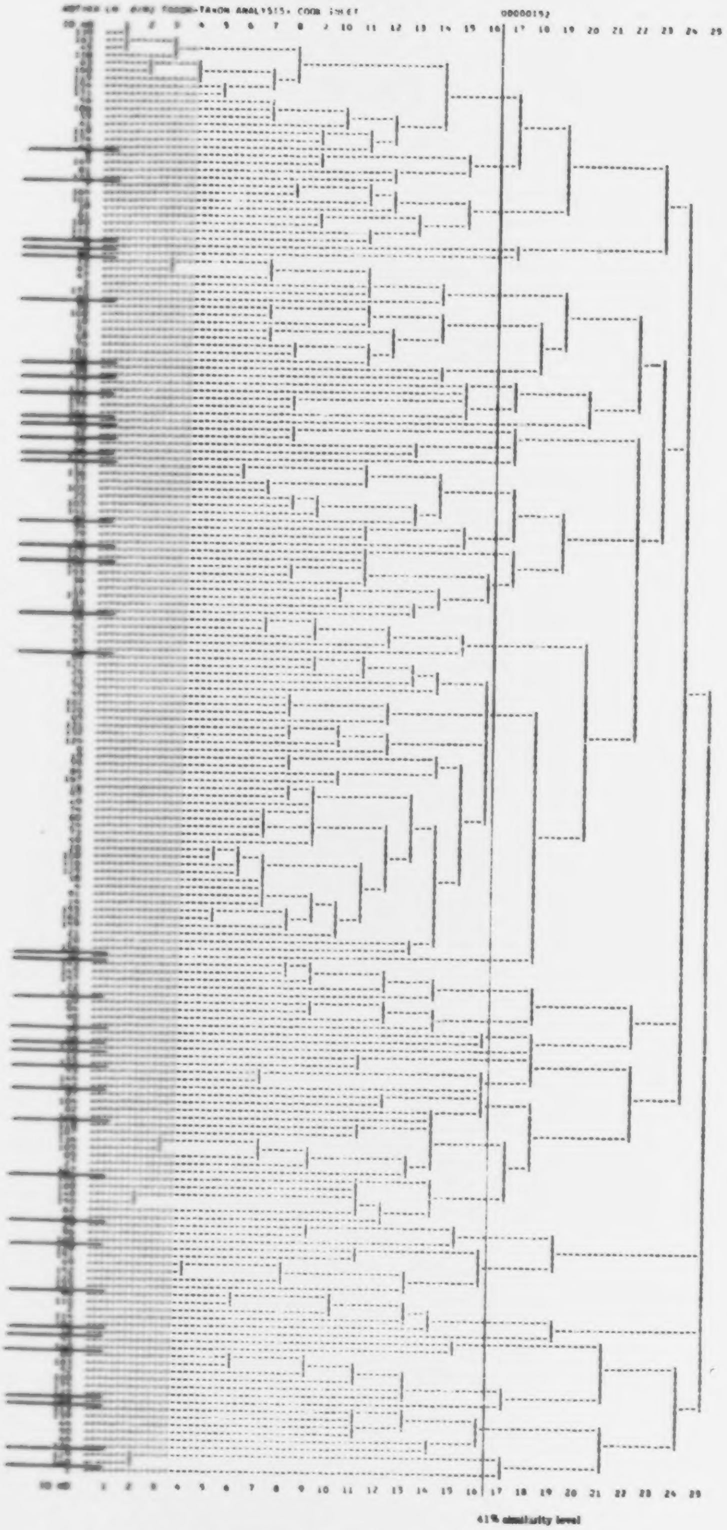

Figure VI.A.4. Cluster analysis comparing taxa on the basis of untransformed abundance data from benthic grabs in Cook Inlet.

SECTION B - FOOD OF SELECTED BENTHIC INVERTEBRATES AND FISHES IN COOK INLET

A detailed survey of the food of commercially important Crustacea and two of their major prey groups, crangonid shrimps and hermit crabs, was undertaken in order to identify key species involved in the flow of carbon to these organisms. The animals examined were snow, king, and Dungeness crabs; hermit crabs; pink, coonstripe, humpy, and crangonid shrimps. Data on the food requirements of zoea larvae of snow crab, king crab, and pink shrimp, juvenile snow crab, and post-larval king crab are included. Additional food data for small numbers of *Crangon communis*, *C. franciscorum*, *Sclerocrangon boreas*, *Argis dentata*, *Oregonia gracilis*, *Hyas lyratus*, *Lebbeus groenlandica* and *Ophiura sarsi* are also included but not discussed. These data are necessary to describe important organisms in the food web of crab and shrimp which may be adversely affected by offshore oil and gas development.

Food of Snow Crab (*Chionoecetes bairdi*)

Food occurred in 772 (64%) of 1198 *Chionoecetes bairdi*, larger than 20 mm, examined (Tables VI.B.I-VI.B.VI). In outer Kachemak Bay (Fig. VI.B.1). Stations 40, 40A, and 41, small clams were the most frequently encountered prey, occurring in 33% of the stomachs. The clams, *Spisula polynyma*, *Nucula tenuis*, and *Macoma* spp. occurred in 16%, 6%, and 4% of the stomachs, respectively. Hermit crabs were observed in 17% of the stomachs and barnacles in 14%. All other prey categories were observed in less than 10% of the stomachs. In inner Kachemak Bay, Station 37, the dominant foods were the clam, *Nuculana fossa*, which occurred in 7% of the stomachs, and polychaetous annelids found in 5% of them.

In Kamishak Bay, Stations 18, 25, 27, 28, 35, 53, 56, PMEL 1 and E1, small bivalves occurred in 37% of the stomachs. *Macoma* spp. were the most frequently occurring clams and were found in 13% of the stomachs. Barnacles and hermit crabs were observed in 19% and 17% of the stomachs, respectively. All other categories of food were observed in less than 10% of the stomachs. Juvenile *Chionoecetes bairdi* were found in four stomachs at Station 23 (Table VI.B.I).

Near the mouth of the Inlet, Stations 5, 5A, 8A, and 23, two food types dominated. Clams of the genus *Macoma* and hermit crabs occurred in 45% and 12% of the stomachs, respectively.

Throughout Cook Inlet, snow crab stomachs with food commonly contained the remains of several barnacles or clams. In one stomach, 16 recently settled *Macoma* spp. were observed. Few stomachs contained more than one large crustacean. The total number of each prey species estimated is presented in Table VI.B.V. These data must be considered qualitative since the estimates are made by counting shell and exoskeletal parts; soft, easily digested tissues are underestimated. Feeding observations in the laboratory have demonstrated that snow crabs may often eat the tissue of small bivalves without ingesting much of the shell.

Little difference was detected in the frequency of occurrence of prey species in *Chionoecetes bairdi* of different sexes or sizes examined (Tables VI.B.V-VI.B.VI).

Barnacles, hermit crabs, crangonid shrimps, and small clams are widely distributed throughout lower Cook Inlet (see Section A), and are apparently fed upon by *Chionoecetes bairdi* in proportion to their abundance. Other species used for food are discontinuous in their distribution in lower Cook Inlet (see Section A). This discontinuous distribution, probably more than their acceptability as food, explains the infrequent occurrence of these species in snow crab stomachs.

Small amounts of sediment were observed in stomachs of crabs from the three areas. Sediment seldom contributed to more than 16% of the dried weight of stomach contents (Table VI.B.VII), and was probably ingested inadvertently or came from the stomachs of prey.

In the Kodiak area the most commonly encountered snow crab stomach contents were small clams, shrimps, plant material, and sediment (Feder *et al.*, 1977; Feder and Jewett, 1977). In Cook Inlet plant material, possibly eelgrass, was only observed in one stomach.

Tarverdieva (1976) found in the southeastern Bering Sea that adult *C. bairdi* fed mainly on polychaetes (60-70%). Echinoderms were found in less than 10% of the stomachs, and molluscs played a large role as food of the young (63%) which live separately from the adults. Commercial-size *C. opilio* fed, as *C. bairdi*, mainly on polychaetes (more than 50% with respect to predominance), and the young crab fed on crustaceans (30-40%), polychaetes (20-30%), and mollusks (20%). Feder *et al.* (1978) reported polychaetes, clams and ophiuroids as important food items for *C. opilio* in the southeastern Bering Sea.

Yasuda (1967) examined stomachs of *Chionoecetes opilio elongatus* Rathbun from Japanese waters, and found the most frequently occurring invertebrate prey to be brittle stars (*Ophiura* spp.), young *C. opilio elongatus*, and protobranch clams. Polychaetes, shrimps, gastropods, scaphopods, and fishes were also taken by *C. opilio elongatus*.

Polychaetes and gastropods were common in Cook Inlet but rarely preyed upon. It is possible that polychaete fragments and setae were not observed with the low-power dissection microscope available on shipboard; and polychaetes may be used more frequently in snow crab stomachs than demonstrated by our analysis. Brittle stars are relatively rare in lower Cook Inlet. In Cook Inlet cannibalism was infrequent. Scaphopods and fishes were encountered in few *C. bairdi* stomachs.

A comparison of the percent fullness of stomachs of Cook Inlet snow crab at different times of day (Table VI.B.VIII) indicates that there are apparently no day-night trends in fullness of snow crab stomachs. These data also indicate the normal degree of stomach fullness encountered in fall, spring, and summer collections. Data on percent fullness of stomachs, average dry weight of stomach contents, and percent tissue weight of stomach contents is presented in Table VI.B.VII).

In the laboratory, total clearance of the stomach required 3 days (Table VI.B.IX). In the laboratory consumption of *Macoma balthica* tissue by snow crab averaged 4.2%, 3.4% and 6.5% of total live weight, total dry weight and dry meat weight of snow crab, respectively (Table VI.B.X). These data may be useful for indicating a change in normal feeding habits resulting from an environmental change, such as oil pollution.

The remains of crustaceans were the most frequently observed items of animal origin in the stomachs of *Chionoecetes bairdi* less than 20 mm carapace width. Fragments of crustacean carapaces that were not identified to a higher taxon were found in 60% of the stomachs. The remains of brachyuran crabs, including *C. bairdi* and *Pinnixa schmitti*, were in 25% of the stomachs. Carapace fragments assigned only to the order Decapoda were present in 12% of the stomachs. The percent frequency of occurrence for bivalves was 38%; *Yoldia* and *Nucula* were the most abundant of the identified clams. Foraminifera were present in 29% of the stomachs. Polychaete and ophiuroid fragments were found in 11% and 9% of the stomachs, respectively (Table VI.B.XI). Sediment, diatoms and sponge spicules were observed in 77%, 29%, and 54% of the stomachs, respectively. The food value obtained from these materials or the bacteria associated with them is unknown. Polychaete setae were present in 54% of the stomachs, and perhaps polychaetes are more important prey than are suggested by the low frequency of occurrence (11%) of polychaete fragments.

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TABLE VI.B.I

FOOD OF COOK INLET SNOW CRAB, OCTOBER 1976. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

			PREY ITEMS																				
Station	No. stomachs examined	No. stomachs with food	Polychaeta	Gastropoda	*Nucella lamellosa*	*Nuculana fossa*	*Yoldia hyperborea*	*Macoma* spp.	*Spisula polynyma*	*Tellina nuculoides*	*Serripes groelandicus*	*Astarte* spp.	Unidentified Bivalvia	Amphipoda	*Balanus* spp.	*Pandalus* spp.	Crangonidae	Paguridae	*Pagurus ochotensis*	*Chionoecetes bairdi*	Unidentified Crustacea	Ophiuroidea	Sediment
5A	38	23		1		5		19													1		
8B	24	14												4		2	2	4			1		
18	79	31				2	1	1			6				12		5	6					16
23	141	106	1					100		1		1			5			15		4			13
25	87	67	3					27				5	2		14		2	5	14	1			5
28	6	3						1										3			1		
40A	96	64	5	1	3				3				1		22			11	23			1	9
41	22	10							9						1		1						2
53	78	43	1					1					2		13		3	6	17		3		8
62A	104	54													6		14	11	30				6
76A	40	13													3		10		2				6
Total Frequency of Occurrence	715	428	10	2	3	7	1	149	12	1	6	6	5	4	76	2	37	61	86	5	6	1	65
Percent Frequency of Occurrence		60	1	0.3	0.4	1	0.1	21	2	0.1	1	1	1	0.5	11	0.3	5	9	12	1	1	0.1	9

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TABLE VI.B.II

FOOD OF COOK INLET SNOW CRAB, NOVEMBER 1977. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS																													
Station	No. stomachs examined	No. stomachs with food	Foraminifera	Polychaeta	Unidentified Bivalvia	*Solariella* sp.*	Unidentified Gastropoda	Scaphopoda	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	Mytilidae	Pectinidae	*Astarte* spp.	*Cyclocardia* spp.	*Spisula polynyma*	*Macoma* spp.	*Balanus* spp.	Amphipoda	Crangonidae	*Pagurus ochotensis*	*Pagurus capillatus*	Unidentified Paguridae	*Cancer* spp.	Unidentified Crustacea	Unidentified tissue	Unid. plant material	Teleost scales	Eggs	Sediment
5	16	15	2	4				1										5		1			3			1				8
27	6	3					1		1							1									2	1				2
35	53	53	2		4	2	3		3	4	5			4	3	2	11	39	1	1	1		22		14	2	2	1		14
40	16	16	8	2	5	1	2		2				1			2	7				1			1	3	7	2			12
53	46	45	3		7	3	1		6	13				1	1	2	17	2			2		9		13	1		1	1	20
62 & 62A	23	14										1						9			1	1	4				1			3
Total Frequency of Occurrence	160	146	15	6	16	6	7	1	12	17	5	1	1	5	4	7	35	55	1	2	5	1	38	1	32	12	5	2	1	59
Percent Frequency of Occurrence		91	9	4	10	4	4	0.6	8	11	3	0.6	0.6	3	2	4	22	34	0.6	1	3	0.6	24	0.6	20	8	3	1	0.6	37

*The genus *Margarites* occurs in the area and may be included.

TABLE VI.B.III

FOOD OF COOK INLET SNOW CRAB, MARCH 1978. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS																							
Station	No. stomachs examined	No. stomachs with food	Hydrozoa	Bryazoa	Polychaeta	*Solariella* sp.*	Unidentified Gastropoda	Gastropoda eggs	*Nucula tenuis*	*Nuculana fossa*	*Yoldia* spp.	*Glycymeris subobsoleta*	*Serripes groenlandicus*	*Spisula polynyma*	*Macoma* spp.	Unidentified Bivalvia	*Balanus* spp.	Crangonidae	Pandalidae	Paguridae	Unidentified Crustacea	Teleost	Plant material	Sediment
5	4	3			1		1								2									
25	23	21	1			2					1	1		1	1	2	2			3	6		1	16
56	12	10		1	1															9				5
62A	48	39	1	1			1	1		1		2	1	1	1	3	1	8	1	20	2	2	1	
E-1	4	3	1						2														1	3
Total Frequency of Occurrence	91	76	3	2	2	2	2	1	2	1	1	3	1	2	4	5	3	8	1	32	8	2	3	24
Percent Frequency of Occurrence		84	3	2	2	2	2	1	2	1	1	3	1	2	4	6	3	9	1	35	9	2	3	26

*The genus *Margarites* occurs in the area and may be included.

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TABLE VI.B.IV

FOOD OF COOK INLET SNOW CRAB, JULY 1979. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	No. stomachs examined	No. stomachs with food	Foraminifera	Hydrozoa	Polychaeta	*Solariella* sp.*	Unidentified Gastropoda	*Nucula tenuis*	*Nuculana fossa*	*Spisula polynyma*	*Macoma* spp.	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Cumacea	Amphipoda	*Crangon* sp.	Paguridae	*Oregonia gracilis*	*Pinnixa* sp.	Unidentified Crustacea	Ophiuroidea	Asidiacea	Unidentified tissue	Plant material
					PREY ITEMS																				
5	72	57			16	1	2		1		7					7	1	18	1		6		2	9	
27	39	8	1					2		5				2	1	1									2
37	15	9			5		2		7				2					2			2			1	
PMEL1	21	17		1	4			8		9		1		1		3	1	3		1	1			1	
40	36	20	1		1	1	1	10	3	16	1			2		3		3			2	2			
41	43	8	1		1					5				4											
62A	6	3			1												1	2							
Total Frequency of Occurrence	232	122	3	1	28	2	5	20	11	35	8	1	2	9	1	14	3	28	1	1	11	2	3	11	2
Percent Frequency of Occurrence		52	1	0.4	12	0.8	2	9	5	15	3	0.4	0.8	4	0.4	6	1	12	0.4	0.4	5	0.8	1	5	0.8

*The genus *Margarites* occurs in the area and may be included.

TABLE VI.B.V

NUMBER OF PREY SPECIMENS IN SNOW CRAB STOMACHS BY SIZE AND SEX, OCTOBER 1976

MF = mature female, MM = mature male, IF = immature female,
IM = immature male

Carapace Width	Number of Stomachs	Sex	Number of Prey in Stomachs	Number of Crab Feeding
Station 5A				
5 - 10	1	IM	Full of sediment	0
61 - 70	2	IM	No food	0
81 - 90	2	IM	Several *Nuculana fossa*	2
91 - 100	2	-	No food	0
101 - 110	2	IM	1 crustacean	1
111 - 120	6	MM	8 *Macoma* spp., 1 *Nuculana fossa*	6
121 - 130	4	MM	2 *Macoma* spp., 1 *Nuculana fossa*, 1 *Balanus* spp.	3
131 - 140	1	MM	Several *Macoma* spp.	1
141 - 150	3	MM	No food	0
71 - 80	2	MF	Several *Macoma* spp.	2
81 - 90	3	MF	Several *Macoma* spp.	3
91 - 100	2	MF	2 *Macoma* spp., 1 *Nuculana fossa*	2
101 - 105	1	MF	1 *Macoma* spp.	1
81 - 90	6	IF	3 *Macoma* spp.	3
91 - 100	2	IF	2 *Macoma* spp.	2
Total	39		Total	26
Station 8B				
5 - 10	4	IM	1 amphipod, 1 crustacean, sediment	2
11 - 20	3	IM	2 tissue, sediment	2
21 - 30	3	IM	1 amphipod, 1 Crangonidae	2
81 - 90	1	IM	1 Paguridae, 1 *Macoma* spp.	1
101 - 110	1	IM	1 Crangonidae	1
5 - 10	9	IF	2 amphipods, 1 tissue, sediment	3
11 - 20	2	IF	1 Natantia, 1 amphipod	2
21 - 30	1	IF	1 Paguridae	1
Total	24		Total	14

TABLE VI.B.V

CONTINUED

Carapace Width	Number of Stomachs	Sex	Number of Prey in Stomachs	Number of Crab Feeding
Station 18				
61 - 70	6	IM	4 *Serripes groenlandicus*	2
71 - 80	16	IM	2 *S. groenlandicus*, 2 Paguridae 3 Crangonidae, 3 *Balanus* spp., sediment	11
81 - 90	19	IM	3 *S. groenlandicus*, 4 Paguridae, 2 Crangonidae, 2 *Balanus* spp., 1 *Pectinaria* spp., sediment	13
91 - 100	13	IM	1 *S. groenlandicus*, 4 *Balanus* spp.	5
101 - 110	15	IM	1 *Macoma* spp., 1 *Nuculana fossa*, 1 Crangonidae, 3 *Balanus* spp., sediment	7
111 - 120	7	MM	No food	0
121 - 130	2	MM	No food	0
141 - 145	1	MM	No food	0
Total	79		Total	38
Station 23				
61 - 70	1	IM	2 *Macoma* spp.	1
71 - 80	9	IM	1 *Yoldia hyperborea*, 17 *Macoma* spp.	7
81 - 90	42	IM	70 *Macoma* spp., 2 *Chionoecetes bairdi*	38
91 - 100	16	IM	13 *Macoma* spp., 1 *C. bairdi*, 1 polychaete, 2 Paguridae, sediment	16
101 - 110	11	IM	4 *Macoma* spp., 2 *Balanus* spp., sediment	7
111 - 120	9	MM	1 Paguridae, 1 *C. bairdi*, 1 *Balanus* spp. 1 Pelecypoda	4
121 - 130	7	MM	1 *Macoma* spp., sediment	1
131 - 140	1	MM	No food	0
141 - 150	2	MM	No food	0
161 - 165	2	MM	No food	0
81 - 90	17	MF	21 *Macoma* spp., 1 *Astarte* spp., 1 Pelecypoda, 1 Gastropoda, 3 Paguridae, sediment	15
91 - 100	12	MF	19 *Macoma* spp., 1 Pelecypoda, 1 Paguridae	9
101 - 110	3	MF	5 *Macoma* spp.	3
71 - 80	5	IF	6 *Macoma* spp.	3
81 - 90	4	IF	3 *Macoma* spp., sediment	3
Total	141		Total	107

TABLE VI.B.V

CONTINUED

Carapace Width	Number of Stomachs	Sex	Number of Prey in Stomachs	Number of Crab Feeding
Station 25				
31 - 40	2	IM	1 *Macoma* spp.	1
61 - 70	2	IM	2 *Macoma* spp.	2
71 - 80	5	IM	1 *Macoma* spp., 1 *Astarte* spp., 1 *Pagurus ochotensis*	3
81 - 90	22	IM	7 *Macoma* spp., 6 *P. ochotensis*, 5 *Balanus* spp., 2 polychaetes, sediment	18
91 - 100	9	IM	2 *Macoma* spp., 4 *P. ochotensis*, 2 Paguridae, 2 *Balanus* spp.	10
111 - 120	3	MM	1 *P. ochotensis*, 1 Paguridae, 1 Crangonidae	3
121 - 130	5	MM	5 *Macoma* spp., 1 *Astarte* spp., 1 *Pandalus* spp., 2 amphipods, 1 polychaete	5
131 - 140	3	MM	1 *P. ochotensis*, 1 *Chionoecetes bairdi*	2
81 - 90	8	MF	2 *Macoma* spp., 1 *Astarte* spp., 1 *P. ochotensis*, 1 *Balanus* spp.	4
91 - 95	1	MF	1 Pelecypoda, sediment	1
21 - 30	3	IF	5 *Macoma* spp.	3
61 - 70	4	IF	2 *Macoma* spp., 1 *Balanus* spp., sediment	3
71 - 80	15	IF	7 *Macoma* spp., 1 *Astarte* spp., 1 Pelecypoda, 1 Paguridae, 1 *Balanus*	11
81 - 90	5	IF	24 *Macoma* spp., 1 Paguridae, 1 Crangonidae	5
Total	87		Total	71
Station 28				
91 - 100	2	IM	1 *Macoma* spp., 2 Paguridae, 1 *Balanus* spp.	2
111 - 120	4	MM	1 Paguridae	1
Total	6		Total	3

TABLE VI.B.V

CONTINUED

Carapace Width	Number of Stomachs	Sex	Number of Prey in Stomachs	Number of Crab Feeding
Station 40A				
41 - 50	9	IM	1 Pelecypoda, 1 *Pagurus ochotensis*, 2 *Balanus* spp., 2 polychaetes, sediment	5
51 - 60	23	IM	11 *P. ochotensis*, 2 Paguridae, 5 *Balanus* spp., 2 polychaetes, sediment	18
61 - 70	30	IM	2 *Spisula polynyma*, 3 *Nucella* spp., 4 *P. ochotensis*, 5 Paguridae, 9 *Balanus* spp., 1 crustacean, 1 Ophiuridae, 1 tissue	22
71 - 80	3	IM	1 *P. ochotensis*, 1 Paguridae, 1 *Balanus* spp., sediment	2
81 - 90	3	IM	1 *P. ochotensis*	1
41 - 50	13	IF	1 *P. ochotensis*, 1 Paguridae, 3 *Balanus* spp., 1 polychaete	6
51 - 60	15	IF	3 *P. ochotensis*, 2 Paguridae, 4 *Balanus* spp., 1 plant material, sediment	10
Total	96		Total	64

TABLE VI.B.VI

FOOD OF COOK INLET SNOW CRAB BY SIZE OF CRAB, NOVEMBER 1977. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Stations 5, 27, 35, 40, 53, 62 & 62A Size of Crab (mm)	No. stomachs examined	No. stomachs with food	PREY ITEMS Foraminifera	Polychaeta	*Solariella* sp.*	Unidentified Gastropoda	Scaphopoda	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	Mytilidae	Pectinidae	*Astarte* spp.	*Cyclocardia* spp.	*Spisula polynyma*	*Macoma* spp.	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	Crangonidae	*Pagurus ochotensis*	*Pagurus capillatus*	Unidentified Paguridae	*Cancer* spp.	Unidentified Crustacea	Unidentified tissue	Unid. plant material	Teleost scales	Eggs	Sediment
0.0 - 9.9	7	6			2				1							3									5					4
10.0 - 19.9	31	29	1		1			3	9				1	1	1	9	4	5			1		6		5	1	1	2		16
20.0 - 29.9	51	46	2	4	2	3	1	3	2	5	1		2	2	2	7	2	29	1	1	1		19		5		1			14
30.0 - 39.9	18	18	3						1				2	1	1	5	2	11					7		9	1				7
40.0 - 59.9	2	2							1									1								1				
60.0 - 79.9	4	4	1	1		2		1				1			1	3	1				1				1					4
80.0 - 99.9	25	23	4	1	1			4	2						2	7	5	6		1	1		4	1	5	2				7
100.0 - 119.9	17	14	2			2		1	1							1	2	3			1	1	2		2	4	2		1	3
>120.0	5	4	2																							3	1			4
Total Frequency of Occurrence	160	146	15	6	6	7	1	12	17	5	1	1	5	4	7	35	16	55	1	2	5	1	38	1	32	12	5	2	1	59
Percent Frequency of Occurrence		91	9	4	4	4	0.6	8	11	3	0.6	0.6	3	2	4	22	10	34	0.6	1	3	0.6	24	0.6	20	8	3	1	0.6	37

* The genus *Margarites* occurs in the area and may be included.

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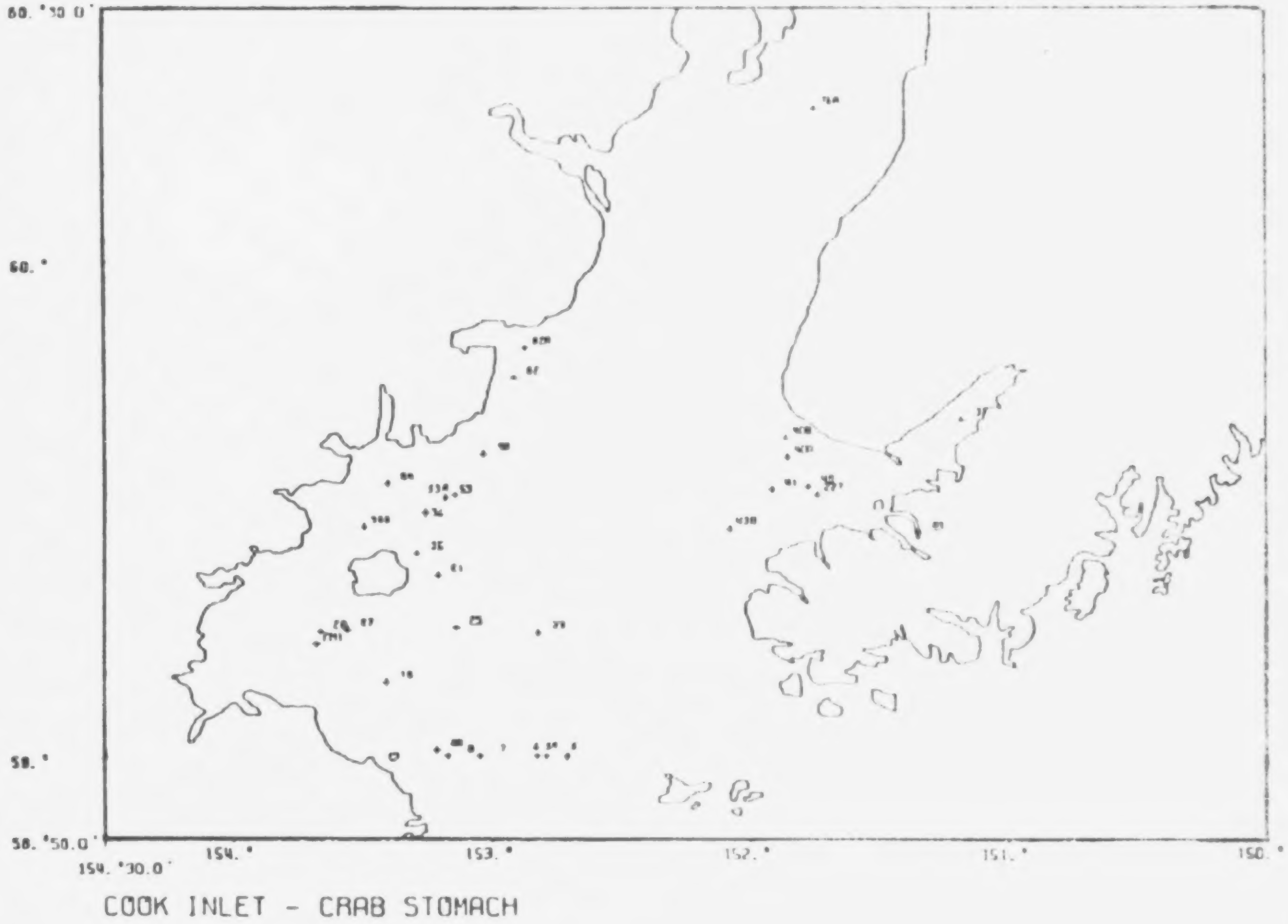
60. °30.0'
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COOK INLET - CRAB STOMACH

Figure VI.B.1. Location of stations where snow crab, king crab and Dungeness crab were captured for stomach analysis.

TABLE VI.B.VII

THE PERCENT FULLNESS OF STOMACH (%f), MEAN DRY WEIGHT (g) OF STOMACH CONTENTS ($\bar{x}$dw), PERCENT OF DRY WEIGHT PLANT AND ANIMAL TISSUE (%t), AND PERCENT SEDIMENT WEIGHT (%s) OF SNOW CRAB, COOK INLET, NOVEMBER 1977

Blanks indicate no specimens at size

Size of Crab	Station 5				Station 27				Station 35				Station 40				Station 53				Station 62, 62A			
(mm)	%f	$\bar{x}$dw	%t	%s	%f	$\bar{x}$dw	%t	%s	%f	$\bar{x}$dw	%t	%s	%f	$\bar{x}$dw	%t	%s	%f	$\bar{x}$dw	%t	%s	%f	$\bar{x}$dw	%t	%s
0 - 9																	-	.028	57	8				
10 - 19	6	.022	82	10					30	.030	60	6					34	.282	77	16				
20 - 29	23	.086	85	13					40	.042	60	13												
30 - 39									35	.176	78	10					29	.082	78	6				
40 - 59									11	.177	90	4												
60 - 79													30	.151	42	25								
80 - 99					8	.212	93	5					29	.213	44	31	19	.275	73	8	16	.135	59	8
100 - 119	0												78	.191	68	16	19	.284	79	10	6	.167	54	3
>120	0												13	.340	67	12	10	.114	83	2				

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TABLE VI.B.VIII

A COMPARISON OF PERCENT FULLNESS OF STOMACHS OF COOK INLET SNOW CRAB AT DIFFERENT TIMES OF CAPTURE

$\bar{x}$ = mean, N = number

Time/day	$\bar{x}$ % Fullness	Station	N
November 1977			
0130	55	53	42
0500	37	40	16
1900	34	35	47
2140	7	5	16
2140	8	27	1
2320	10	62, 62A	10
March 1978			
0000	28.6	62A	6
0335	50.0	62A	4
0740	60.0	62A	1
0815	38.1	25	21
1040	25.0	62A	1
1206	60.2	62A	6
1402	100.0	62A	1
1440	62.8	62A	2
1537	45.0	62A	2
1700	50.0	62A	2
2206	72.2	62A	3
July 1978			
0530	14	40	18
1100	5	37	6
1430	24	PMEL1	12
1800	54	62A	2
1800	15	5	46

TABLE VI.B.IX

PERCENT FULLNESS OF STOMACHS OF SNOW CRAB AFTER FEEDING IN THE LABORATORY (5°C)

N = Number of specimens examined

Time After Feeding (hrs)	N	Mean Carapace Width (mm)	Mean Percent Stomach Fullness	Standard Deviation
Experiment 1				
24	5	62	11.0	6.8
32	5	51	5.6	2.4
44	5	55	6.7	5.1
56	5	53	3.4	3.2
80	5	52	1.5	0.5
Experiment 2				
24	5	47	7.3	2.3
48	5	43	4.8	2.8
72	5	45	2.4	1.1

TABLE VI.B.X

CONSUMPTION OF *MACOMA BALTHICA* BY SNOW CRAB OVER A TWENTY-FOUR HOUR PERIOD

$\bar{x}$ = mean, N = number of specimens

$\bar{x}$ Carapace Width (mm)	N	Whole Crab Weight (g)	Mean *Macoma* Meat Weight Eaten (g)	Standard Deviation	*Macoma* Meat as % Crab Weight
Wet Weight Basis					
42	5	19.5	1.630	1.2337	8.4
50	4	35.2	0.7422	0.2672	2.1
51	5	35.2	0.9917	0.5408	2.8
72	2	107.5	3.6918	1.7976	3.4
					$\bar{x}$ 4.2
Dry Weight Basis					
42	5	5.4	0.4315	0.3266	7.9
50	4	9.3	0.0915	0.3929	1.0
51	5	10.2	0.2917	0.1591	2.9
72	2	30.1	0.5067	0.2466	1.7
					$\bar{x}$ 3.4

$\bar{x}$ Carapace Width (mm)	N	Dry Crab Meat Weight	Mean *Macoma* Dry Meat (g) Weight Eaten	Standard Deviation	*Macoma* Meat as % Crab Weight
42	5	2.8	0.4315	0.3266	15.4
50	4	4.6	0.0915	0.3929	1.9
51	5	5.1	0.2917	0.1591	5.7
72	2	15.4	0.5067	0.2466	3.2
					$\bar{x}$ 6.5

TABLE VI.B.XI

FOOD OF COOK INLET SNOW CRAB LESS THAN 20 mm WIDTH
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

						PREY ITEMS																																						
Station	Date month/year	Depth (m)	$\bar{x}$ carapace width (mm)	Number of stomachs examined	Number with food	Diatoms	Algae	Foraminifera	Tintinnida	Hydrozoa	Bryozoa	Unid. organisms (Flagellates?)	Porifera spicules	Polychaete setae	Polychaeta	Gastropoda	Scaphopoda	*Nucula tenuis*	*Yoldia* spp.	*Axinopsida* sp.	*Odontogena* sp.	*Cyclocardia* sp.	*Macoma* sp.	Unid. Bivalvia	Harpacticoida	Ostracoda	Cirripedia	Cumacea	Amphipoda	Pandalidae	Paguridae	*Pinnixa schmitti*	*Chionoecetes bairdi*	Unid. Brachyura	Unid. Decapoda	Unid. fragments of Crustacea	Pycnogonida	Ophiuridea	Holothuroidea plates	Unid. egg case	Teleost scale	Unid. tissue	Unid. organic material	Sediment
5	4/76	166	20	99	98	47	1	52	2	1		4	15	69	5	14	1	1	1	1	6	1	1	26	2	1			8	2	7		21	14	7	38	3	3	4	18	1	1	2	90
5	3/78	166	16	50	49	10	3	33				1	4	36	6	1								9	1	1			1						11	36		22		4		5	4	49
7	4/76	157	20	50	49	13	1	18	1	3			15	20	7	1	2		1					17						4			3	18	2	39		2				5	17	45
8	4/76	136	20	50	50	10	5	8					9	21	5									1									2		3	37		1		4		12	21	45
8	3/78	136	18	48	44	1	1	9						10	3	2								6			1							8	8	18						7		23
18	3/78	44	18	50	49	12	9	6						33	5	2			9					20	7								2	12	12	35		5	3		1	10	4	41
28	4/76	31	16	8	8			2							4	1		2						7	4	7			1							2				1				1
36	4/76	33	18	35	35	15	2	4					4	25	5				1			3		26	3								1	5	1	26		7		2	1	6	10	
49	4/76	40	21	25	25	1	1	6		1				12	3	1		10		1				8	3										7	8	1			3			1	22
51	4/76	35	28	10	10	2	2				2		1	7	1														1		5	5	2	4	1	9		1		1		1	4	9
62A	4/78		17	50	49	26	5	17			4		1	26	9				21					15				3		2			2	18	5	38		2		3		6	2	43
Total Frequency of Occurrence				475	466	137	30	138	3	5	6	5	49	258	53	22	3	13	33	2	6	4	1	135	20	9	1	3	11	8	12	5	33	79	57	286	4	43	7	36	3	53	65	368
Percent Frequency of Occurrence					98	29	6	29	>1	1	1	1	10	54	11	5	>1	3	7	>1	1	1	>1	28	4	2	>1	>1	2	2	3	1	7	17	12	60	1	9	1	8	>1	11	14	77

Food of King Crab (*Paralithodes camtschatica*)

A total of 117 king crab stomachs were examined from Kamishak Bay (Fig. VI.B.1), 90% contained food. The mean carapace length of all crab examined was 105 mm with a range of 35-150 mm. The three most frequently observed individual foods were barnacles, 81%; bivalves of the family Mytilidae, probably *Modiolus* sp., 13%; and hermit crabs, 12%. In addition, 17 other categories of food items were observed; none occurred in more than 6% of the stomachs. Bivalves (clams), all species combined, occurred in 27% of the stomachs, and gastropods were found in 12% of the stomachs (Table VI.B.XII). In May, 41% of the crabs with empty stomachs were newly molted or molting individuals.

Stomachs from crabs in Kamishak Bay (Fig. VI.B.1) often contained only barnacle remains. Thirty king crabs, *Paralithodes camtschatica*, collected at Station 35 had full stomachs. All crabs had barnacles in their stomachs; 60% of these crabs were feeding exclusively on barnacles. The stomach contents of all king crabs feeding exclusively on barnacles were digested in KOH, and the shell weight remaining after KOH digestion determined. In addition, the average shell weights of barnacles, randomly selected and counted on pieces of pumice taken in trawls, were determined in a similar manner. Utilizing this data, an estimation of the average number of barnacles in each of the king crab stomachs was made. The stomachs contained barnacle shells equivalent to an average of 11.2 (S.D. = 7.4) barnacles per crab. King crabs were not present in trawl catches from Station 35 in 1976; this suggests that this predator has been attracted by the presence of barnacles, a new and abundant food source.

In Kachemak Bay, 113 king crabs were captured, 72% contained food (Table VI.B.XIII). Bivalves, all species together, occurred in 60% of the stomachs. The clam, *Spisula polynyma*, was the most frequently occurring prey species, observed in 38% of the stomachs. Barnacles were found in 14% of the stomachs. The snail, *Neptunea lyrata*, occurred in 11% of the stomachs. By examining shell thickness and sizes of resilium or cardinal teeth of *Spisula polynyma* shells in stomachs, it was possible to estimate sizes and age of the clams eaten (see Section C for size and age data). In the 43 king crab stomachs containing *S. polynyma*, 13 had large clam meats and pieces of shell 1 to 2 mm thick. *Spisula polynyma* with shell this thick would exceed 80 mm in shell length and be seven years of age or older. Shells of *S. polynyma*, less than 10 mm in length (young-of-the-year or one-year-old clams) occurred in 30 stomachs. Pieces of *Neptunea lyrata* opercula up to 15 mm in length were found in the stomachs of adult crabs.

In contrast to Kamishak Bay, king crab in Kachemak Bay, generally contained the remains of a variety of organisms. For example, one specimen contained 21 small *Spisula polynyma*, two *Solariella* sp. (snail), one *Oenopota* sp. (snail), and *Balanus* sp. shell.

Sixteen king crabs were captured at Station 6 near the mouth of the Inlet. In the 12 that contained food, 10 had eaten *Nuculana fossa*. These stomachs contained between 10 and 25 of these small bivalves. Clams of the genus *Macoma* occurred in four stomachs, and one crab had unidentifiable crustacean remains.

Tarverdieva (1976) provides information on feeding of king crabs from Bristol Bay, Alaska. There, echinoderms and molluscs were the predominant food items occurring in 50% and 35% of the stomachs respectively. Feder *et al.* (1978) observed *Clinocardium ciliatum* in 67%, *Solariella* spp. in 55%, *Nuculana fossa* in 50%, *Cistenides* sp. and brittle stars of the family Amphiuridae in 35% of 124 king crab stomachs from the southeastern Bering Sea. Takeuchi (1968a, b) examined the food of king crabs from the Kamchatka region of Japan, and found that molluscs, crustaceans, and echinoderms were the main food items. Takeuchi (1968b) found that the frequency of occurrence of the above prey groups in crab stomachs corresponded to the relative abundance of these organisms. In Cook Inlet, barnacles, clams, snails, and hermit crabs are widely distributed (Section A) and are fed upon in proportion to their abundance. At the stations examined, small echinoderms were relatively rare (Section A).

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TABLE VI.B.XII

FOOD OF COOK INLET KING CRAB, KAMISHAK BAY.
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

				PREY ITEMS																			
Station	Date month/year	No. stomachs examined	No. stomachs with food	Hydrozoa	Bryozoa	Polychaeta	*Solariella* sp.*	*Polinices* spp.	*Neptunea lyrata*	Unidentified Gastropoda	Gastropod eggs	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	Mytilidae	*Macoma* spp.	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	Paguridae	Unidentified Crustacea	Plant material
18	6/78	5	5				4	1		1		2	1	2		1			5	1	1		
27	6/78	30	30	2	1		1			1	2				14		1	1	30		9		
35	11/77	36	36			1			1	1			1	1	1				29		1		1
35	5/78	22	17										2						17				1
35	6/78	13	13	1				1		1			1					1	13		3		
36	5/78	3	1													1			1				
36B	5/78	2	0																				
53	11/77	3	3						1	1			2							1		1	
54	5/78	3	0																				
Total Frequency of Occurrence		117	105	3	1	1	5	2	2	5	2	2	7	3	15	2	1	2	95	2	14	1	2
Percent Frequency of Occurrence			90	3	1	1	4	2	2	4	2	2	6	3	13	2	1	2	81	2	12	1	2

*The genus *Margarites* occurs in the area and may be included.

TABLE VI.B.XIII

FOOD OF COOK INLET KING CRAB, KACHEMAK BAY.
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

		PREY ITEMS																													
Station	Date month/year	No. stomachs examined	No. stomachs with food	Foraminifera	Hydrozoa	Bryozoa	Polychaeta	*Solariella* sp.*	*Neptunea lyrata*	*Oenopota* spp.	Unidentified Gastropoda	Gastropod eggs	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	*Modiolus modiolus*	*Chlamys* spp.	*Clinocardium ciliatum*	*Spisula polynyma*	*Macoma* spp.	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	*Pandalus* spp.	Paguridae	Unidentified Crustacea	Ophiuroidea	Asteroidea	Unidentified tissue	Plant material
40	6/78	1	1						1		1							1								1		5			
40	7/78	35	29	1		1	3	6	2	9	1		3	3		2			26	2			2	1	9	1	1				
40A	6/78	42	36	2	8			2	8		3				1	2	1	1	13	2		1	9				3	1		2	3
40B	6/78	3	2		1	1	1	1	1		1	1					1		1			1	1					1			
41	6/78	2	2	1			1												2				1			1			1		
43A	3/78	28	10	1	8	1										1					1	1	3			5			2		1
227	8/78	2	1											1					1											1	
Total Frequency of Occurrence		113	81	5	17	3	5	9	12	9	6	1	3	4	1	5	2	2	43	4	1	3	16	1	9	8	4	7	3	3	4
Percent Frequency of Occurrence			72	4	15	3	4	8	11	8	5	1	3	4	1	4	2	2	38	4	1	3	14	1	8	7	4	6	3	3	4

*The genus *Margarites* occurs in the area and may be included.

Food of Post-Larval King Crab (*Paralithodes camtschatica*)

Sediment was found in 93% of the post-larval king crab stomachs (Table VI.B.XIV; Fig. VI.B.2). This high incidence of occurrence suggests that foraging in the sediment is a common method of feeding. Diatoms (27%) and tintinnids (7%) which have settled to the bottom, are also commonly ingested. Sponge spicules, found in 60% of the stomachs, are common in subtidal sediments. No identifiable pieces of sponge tissue were observed in the stomachs. Sponges are seldom eaten by benthic predators; however, some nudibranchs and crustacean inhabitants of sponges feed on them (Hyman, 1940). The importance of sponges as food to post-larval king crab cannot be determined from stomach analysis alone.

Pieces of algae and the bryozoan, *Flustrella*, were observed in 9% and 11% of the stomachs, respectively. Neither algae nor bryozoans appeared to contribute significantly to the volume of the material present in the stomachs. Therefore, the algae and Bryozoa appear to provide a suitable habitat rather than actual food for the young crab.

Seventy percent of the stomachs contained significant amounts of unidentifiable organic material, possibly detritus. This material may also have been a mixture of sediment and semidigested tissue and, because of its unknown nature, is recorded as unidentified organic material. Detritus and associated bacteria have been demonstrated to be important to the nutrition of some crustaceans (Fenchel and Jørgensen, 1977; Moriarty, 1976; Rieper, 1978).

Small crustacean fragments were found in 64% of the stomachs. Harpacticoid copepods and ostracods were the most prevalent identifiable crustaceans, found in 8% and 9% of the stomachs, respectively. Polychaete setae were found in 31% of the stomachs. Only three observations of setae associated with polychaete tissue were made. Foraminifera were observed in 27%, and unidentified Protozoa in 6% of the stomachs.

Marukawa (1933) suggests that the glaucothoe of king crab feed on bryozoans and detritus. This study indicates that post-larval king crab ingest significant quantities of detritus and some Bryozoa, but that the crab also takes Protozoa, harpacticoid copepods and ostracods. The ability of post-larval king crab to utilize detritus and sediment together with associated bacteria as food needs to be investigated.

TABLE VI.B.XIV

THE FOOD OF COOK INLET POST-LARVAL KING CRAB, KACHEMAK BAY
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

				PREY ITEMS																						
Station	Depth (m)	x̄ carapace length	x̄ carapace width	No. stomachs examined	No. with food	Diatoms	Silicoflagellates	Algae	Foraminifera	Tintinnida	Unid. organisms (Mastigophora)	Porifera spicules	Hydrozoa	*Flustrella*	Polychaete setae	Bivalvia	Harpacticoida	Ostracoda	Decapoda fragments	Unid. fragments of Crustacea	Asteroid ossicles	Echinodermata spines	Unid. tissue	Unid. organic material	Sediment	Nylon rope fiber
58	13	3.99	3.79	6	6	1			3			6		1	1	1	1	1		1				1	6	1
59	16	5.00	4.46	14	14	7			8	1	7	13	1	2	5		5	1		6				13	14	
60	18	3.87	3.44	4	4			1	1	1		1		1	1		2	1		1				4	4	1
61	13	4.20	3.75	2	2							2			17					2				2	2	
62	22	4.75	4.18	25	24	7			9		1	16		2		1		1	3	23				24	24	
DS 1	12	3.20	2.86	34	34	1	1	6	8	4	2	19		6	9	2	3	5	2	8	1		10	15	34	
DS 2	6	3.27	2.89	6	6	1		1		2					1					4			2	2	6	
105	14	4.42	4.01	2	2				1			2								1				2		
106	20	4.11	3.89	2	2	1						1			2					2				2	2	
107	27	3.82	3.57	2	2	1			2			2			1									2	2	
108	20	4.17	3.61	4	4	2						2					1						3	4	4	
109	27	4.34	3.71	2	1																		1		1	
110	22	4.19	3.64	13	13	5			1			7			4		2	2		9			2	13	13	
112	23	5.04	4.87	5	5	2			2			4			1					3				3		
DS 4	15	3.35	2.91	6	6	3			2		1	2			4			1		2		1	1	5	4	
DS 5	31	2.89	2.56	37	36	15		6	9	4		25		6	7	1		2		14	1	3	7	23	36	
28	5	3.35	3.06	8	8			2	1			1						2		2			5	6	8	
Total Frequency of Occurrence				172	169	46	1	16	47	12	11	103	1	18	53	5	14	16	5	78	2	4	31	121	160	2
Percent Frequency of Occurrence					98	27	0.5	9	27	7	6	60	0.5	10	31	3	8	9	3	45	1	2	18	70	93	1

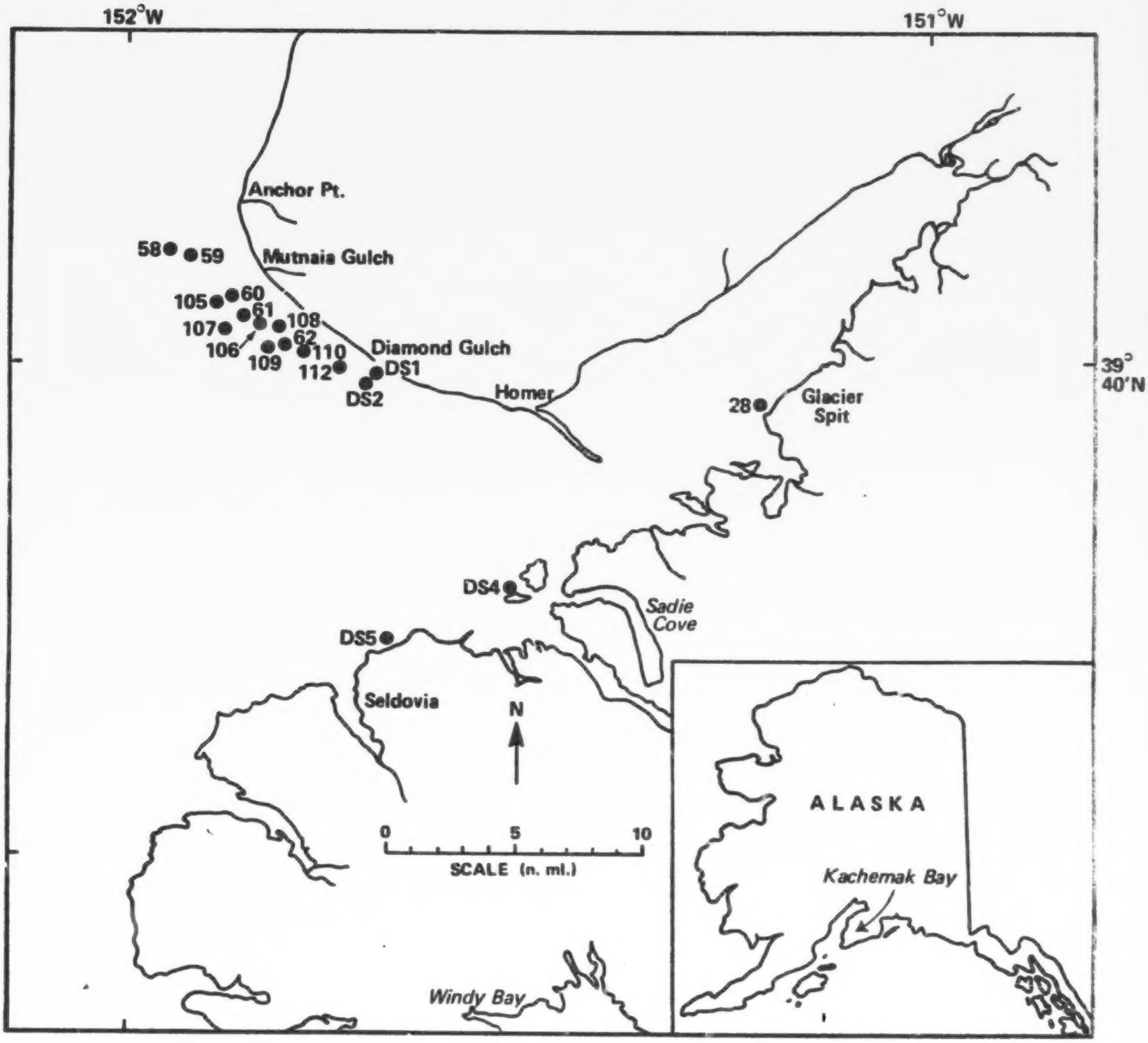
152°W
151°W
Anchor Pt.
Mutnaia Gulch
58
59
105
60
61
107
108
106
62
109
110
Diamond Gulch
112
DS1
DS2
Homer
28
Glacier Spit
39°
40'N
DS4
Sadie Cove
DS5
Seldovia
N
0
5
10
SCALE (n. mi.)
Windy Bay
ALASKA
Kachemak Bay

Figure VI.B.2. Map of Kachemak Bay showing location of bottom skimmer tows and suction dredge stations where post-larval king crab were collected for stomach analysis.

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Food of Dungeness Crab (*Cancer magister*)

Food occurred in 331, 80%, of the 413 Dungeness crab, *Cancer magister*, stomachs examined (Tables VI.B.XV-VI.B.XVI; Fig. VI.B.1). The average shell width of the Dungeness crab examined was 142 mm with a range of 22 to 210 mm. Individuals over 50 mm carapace width preyed primarily on small bivalves, barnacles, and amphipods (Table VI.B.XV). Small clams were the most important food items, and were present in 67% of the stomachs. Young *Spisula polynyma* was the most frequently occurring prey, observed in 48% of the stomachs. All other prey species occurred in less than 5% of the stomachs examined.

In 93% of the *Cancer magister* stomachs containing *Spisula polynyma*, the shell fragments belonged to clams less than 10 mm in shell length (young-of-the-year or one-year-old clams). By counting the number of umbos or hinge ligaments present, it was possible to make an estimate of the number of small *S. polynyma* present in some stomachs. The maximum number countable in one stomach was 125 young clams. The meats of large *S. polynyma* and pieces of shell 1 to 2 mm thick were observed in 29 stomachs.

In one sample of *Cancer magister*, composed of crabs with carapace widths of 22 to 45 mm (Table VI.B.XVI), the most frequently occurring animals were Foraminifera, 36%; Polychaeta, 28%; barnacles, 28%; and small clams 25%. The individuals with empty stomachs were generally in a newly molted or molting condition.

In a northern California study, the five most frequently observed categories of prey for *Cancer magister* were clams, 35%; fishes, 24%; isopods, 17%; amphipods, 16%; and razor clams (*Siliqua patula*), 12% (Gotshall, 1977). Butler (1954) examined *C. magister* from British Columbia, Canada, and found that crustaceans (59%) and clams (56%) were the most frequently occurring food items. Butler (1954) reported fish remains in only four Dungeness stomachs. The results of these two studies are similar to our data in that all of the investigations show that clams and several kinds of crustaceans are important as prey for *C. magister*. The major difference between the studies is the importance of fishes in the diet of northern California Dungeness crabs, and the low frequency of occurrence of fishes in crab diets in British Columbia and Cook Inlet. Isopods or razor clams were rarely encountered in grabs or dredges in Cook Inlet. The mollusc most commonly taken by dredging, and found in the stomachs of other predators in the study area, was *Spisula polynyma*. Therefore, the high incidence of predation on this species is probably a reflection of its abundance.

TABLE VI.B.XV

FOOD OF COOK INLET DUNGENESS CRAB CARAPACE WIDTHS GREATER THAN 50 mm. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	Date month/year	No. stomachs examined	No. stomachs with food	Foraminifera	Hydrozoa	Bryozoa	Polychaeta	*Solariella* sp.*	*Natica* sp.	*Neptunea lyrata*	Unidentified Gastropoda	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	*Modiolus modiolus*	*Chlamys* spp.	*Clinocardium ciliatum*	*Spisula polynyma*	*Macoma* spp.	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	*Pandalus* spp.	*Crangon* spp.	Paguridae	*Chionoecetes bairdi*	Unidentified Crustacea	Ophiuroidea	Teleost	Unidentified tissue	Plant material
40	7/78	25	18						1		1		6					11	1	1	8	1			1	1			1			
40	8/78	52	40							1		10	7					33			6	1	1	1	1	1			2	1		
40A	12/77	18	12	3			2	3										9	1			2				1			2			
40A	6/78	132	104	5	1	1	5	2						3		6		80	3		5	2	10	10			1	6	3	4	2	
40A	7/78	9	5	4			1											2				3	1									
40A	8/78	6	5	1			1	1										2					2	2						1		
41	6/78	3	3															3														
41	7/78	22	21	1			1		1									9		1		10	1			2						
41	8/78	13	8	2														5			1	3			1	1						
227	8/78	6	2															1							1							
D1	8/78	63	33	1			6								7		4	13				17	6			9		4		2	6	4
Total Frequency of Occurrence		349	251	17	1	1	16	6	2	1	1	10	13	3	7	6	4	168	5	2	20	39	21	13	4	15	1	10	8	8	8	4
Percent Frequency of Occurrence			72	5	<1	<1	4	2	<1	<1	<1	3	4	1	2	2	1	48	1	<1	6	11	6	4	1	4	<1	3	2	2	2	1

*The genus *Margarites* occurs in the area and may be included.

TABLE VI.B.XVI

FOOD OF COOK INLET *CANCER MAGISTER*, CARAPACE WIDTHS OF 22-45 mm. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

		PREY ITEMS															
Station	Date month/year	No. stomachs examined	No. stomachs with food	Foraminifera	Polychaeta	*Solariella* sp.*	Unidentified Gastropoda	*Nucula tenuis*	*Spisula polynyma*	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	Paguridae	Unidentified Crustacea	Unidentified tissue	Sand
40A	8/78	64	51	23	18	2	1	1	9	1	6	18	1	8	2	2	27
Total Frequency of Occurrence		64	51	23	18	2	1	1	9	1	6	18	1	8	2	2	27
Percent Frequency of Occurrence			80	36	28	3	2	2	14	2	9	28	2	13	3	3	42

*The genus *Margarites* occurs in the area and may be included.

Food of Pink Shrimp (*Pandalus borealis*)

A total of 233 *Pandalus borealis* stomachs were examined from lower Cook Inlet; 82% (192 individuals) contained food (Table VI.B.XVII; Fig. VI.B.3). The three most frequently observed items were unidentified Crustacea, frequency of occurrence 47%; unidentified Polychaeta, 21%, and diatoms, 16%. Additional crustaceans identified to lower taxa were Decapoda, 5%; and Ostracoda, 3%. Other polychaetes included Spionidae, 5%; Nephtyidae, 2%; and *Lumbrineris* sp., 2%. The centric diatom *Melosira sulcata* and naviculoid diatoms were frequently observed. Other food items included small unidentified clams, 16%; *Nucula tenuis* was observed in an additional 6% and *Nuculana* spp. in 3% of the stomachs with food. Foraminifera were observed in 14% of the stomachs; Teleostei remains in 5% and plant material in 3%. Pink shrimp stomachs typically contained a variety of items. For example, the stomach of one shrimp, carapace length 19 mm, contained an intact *Nuculana* sp., numerous crustacean fragments, four Foraminifera, unidentifiable fibers, numerous *Melosira sulcata*, and unidentifiable spines. Unidentified organic matter was frequently observed, 37% frequency of occurrence, and sediment was common, 44%. In addition, sediment constituted 60% of the dry weight of stomach samples so analyzed (Table VI.B.XVIII). Fifteen additional food categories were infrequently observed in pink shrimp specimens (Table VI.B.XVII).

Prey frequency of occurrence data for pink shrimp from Station 37 (7/78) were examined for differences between males and females. Chi-square analysis of the five most frequent food categories revealed no significant differences in frequencies.

TABLE VI.B.XVII

FOOD OF COOK INLET PINK SHRIMP
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

						PREY ITEMS																												
Station	Date month/year	Depth (m)	No. stomachs examined	No. with contents	Diatoms	Plant material	Foraminifera	Porifera	Hydrozoa	Anthozoa	Nematoda	Polychaeta	Polynoidae	Syllidae	Nepthyidae	*Lumbrineris* sp.	Spionidae	Maldanidae	Sabellidae	Gastropoda	Bivalvia	*Nucula tenuis*	*Nuculana* sp.	*Yoldia* sp.	Crustacea	Ostracoda	Harpacticoid copepods	Cumacea	Decapoda	Brachyura	Enchinodermata	Chaetognatha	Teleost	Unid. organic material	Sediment
350	11/77	210	50	22			5					4				1	1	1			2				6		1	1		1			1	2	11
PMEL 7	7/78	84	19	17	7		6					6				1	1				9	1	2		15				1				1	11	17
5	3/78	170	21	18	1		2					7				1	1				1	1			13				1					8	12
37	11/77	42	43	42	2	2	13	1		1	1	13		1				1	1		21	10	6	1	33	8	1		3			2	9	16	22
37	5/78	60	50	47	23	2	2					5			3		2								4				5					41	
37	7/78	52	50	46	5	2	5					15	3		2	2	7		1		4	1			38				1		1		1	8	41
Total frequency of occurrence			233	192	38	6	33	1		1	1	50	3	1	5	5	12	2	2		37	13	8	1	109	8	2	1	11	1	1	2	12	86	103
Percent Frequency of occurrence			100	82	16	3	14	<1		<1	<1	21	1	<1	2	2	5	1	1		16	6	3	<1	47	3	1	<1	5	<1	<1	1	5	37	44

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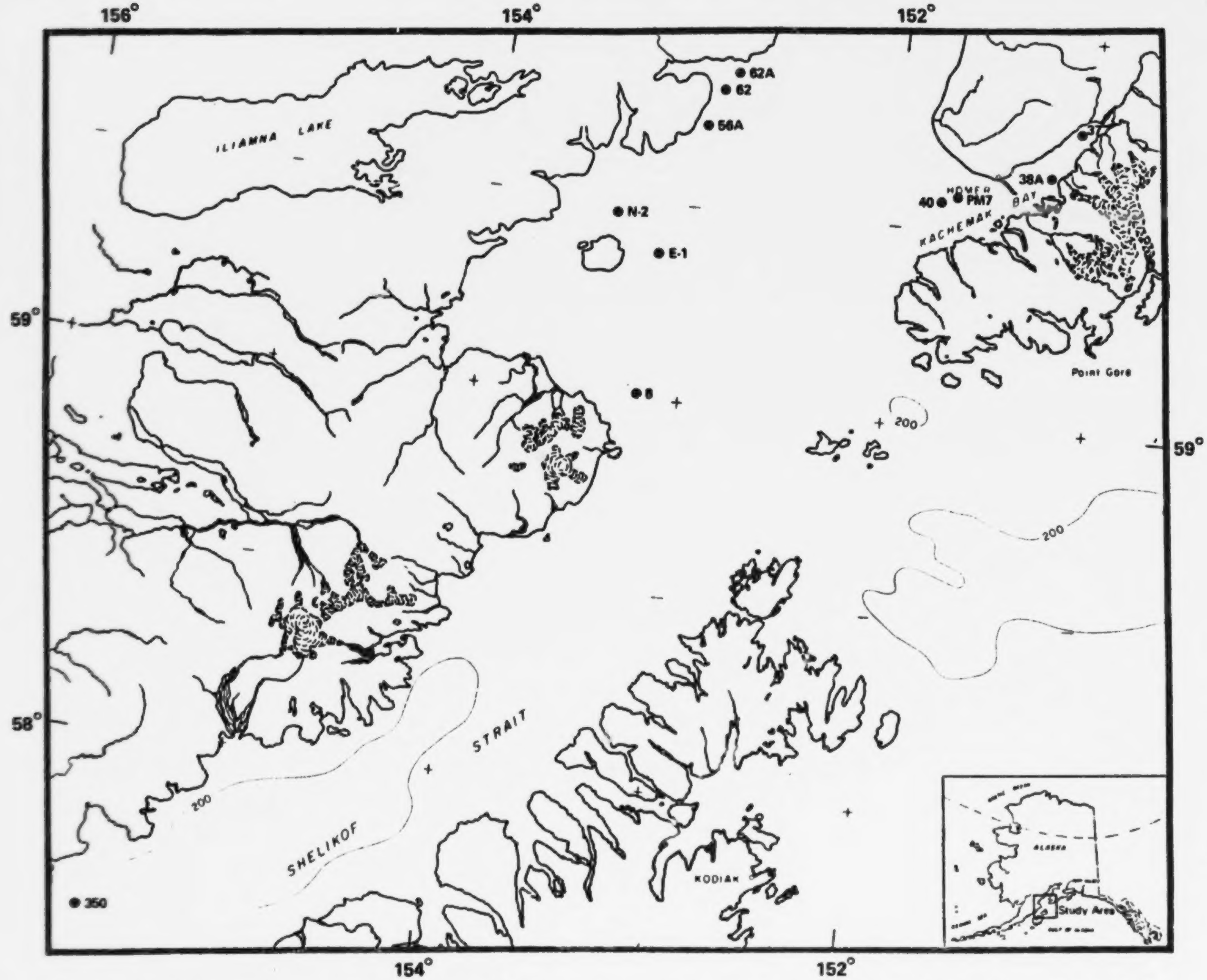
TABLE VI.B.XVIII

TOTAL DRY WEIGHT OF SHRIMP STOMACH CONTENTS AND PERCENTAGE OF DRIED STOMACH CONTENTS COMPOSED OF SEDIMENT

Animal	Station	Date	No. stomach contents	Total dry wt. stomachs contents (g)	Total dry wt. sediments in stomachs after KOH, KCl digestion treatment	% of dried stomach contents sediment
Pandalus goniurus	62	3/78	18	.525	.320	61%
Pandalus goniurus	8	6/78	52	.775	.494	64%
Pandalus hypsinotus	PMEL 7	7/78	3	.123	.108	88%
Pandalus hypsinotus	40	7/78	12	.407	.250	61%
Pandalus hypsinotus	38A	3/78	8	.121	.062	51%
Pandalus hypsinotus	37	7/78	50	1.152	.827	72%
Pandalus borealis	PMEL 7	8/78	37	.428	.267	62%
Pandalus borealis	37	8/78	25	.285	.164	58%
Control	-	-	-	.780	.556	-
(Sand .565 gm Tissue .215 gm)						



156°
154°
152°
59°
58°
ILIAMNA LAKE
62A
62
56A
N-2
E-1
8
40
PM7
38A
HOMER
KACHEMAK BAY
Point Gore
200
SHELIKOF
STRAIT
KODIAK
350
ALASKA
Study Area

Figure VI.B.3. Lower Cook Inlet, Alaska, and stations where pandalid shrimp were collected for stomach analysis.

Food of Coonstripe Shrimp (*Pandalus hypsinotus*)

One hundred ninety-five *Pandalus hupsinotus* stomachs were examined; 80% (157 individuals) contained food (Table VI.B.XIX; Fig. VI.B.3). The three most frequently identified stomachs items were unidentified Crustacea, 49% frequency of occurrence, unidentified Polychaeta, 39%; and unidentified small clams, 9%. Common and additional crustaceans identified to a lower taxon included Decapoda, 5%. Additional polychaetes included *Disoma multisetosum*, 9%; Polynoidae, 8%; and Spionidae, 5%. An additional bivalve, *Nucula tenuis* was observed in 17% of the stomachs. Other food items included Teleostei, 7%; sponge spicules, 6%; diatoms, 5%; plant material, 5%; and Foraminifera, 5%. Eight other food categories were infrequently observed (Table VI.B.XVII). The coonstripe shrimp stomachs contained a variety of organisms. For example, the stomach of one shrimp, carapace length 22.5 mm, contained an intact *Nucula tenuis* (2 mm in length), numerous crustacean fragments, and broken polychaete setae. Another individual, carapace length 32 mm, contained 17 intact *Nucula tenuis* (2-4 mm), terebellid polychaete setae, naviculoid diatoms, and unidentified tissue.

Unidentifiable organic matter was frequently observed, 29% frequency of occurrence, and sediment was common. Sediment averaged 68% of the dry weight of stomach contents so analyzed (Table VI.B.XVII).

Prey frequency of occurrence data for coonstripe shrimp from Station 56A (3/78) were examined for differences between males and females. Chi-square analysis of the 5 most frequent categories revealed no significant differences in frequencies.

TABLE VI.B.XIX

FOOD OF COOK INLET COONSTRIPE SHRIMP
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	Date month/year	Depth (m)	No. stomachs examined	No. with contents	Diatoms	Plant material	Foraminifera	Porifera	Hydrozoa	Polychaeta	Polynoidae	Nethyidae	Spionidae	*Disoma multisetosum*	Maldanidae	Terebellidae	Sabellidae	Bivalvia	*Nucula tenuis*	*Nuculana* sp.	Crustacea	Harpacticoid copepod	Decapoda	Echinodermata	Teleost	Unid. organic material	Sediment
					PREY ITEMS																						
56A	3/78	31	20	18	2				3	16	4				1	1			6		9		4			11	15
40	7/78	56	18	12						1									2					1		5	9
38A	3/78	55	18	9	1	1				3											3			1		5	4
37	11/77	42	50	43	1	1	6		1	16	5	2	1	2	6	2		9	16		24	3	4	3	7	11	24
37	3/78	50	32	25	1	2	2			14	2	1			1		1	1	6	1	17			1	5	18	16
37	5/78	60	7	5																	4		1		1	1	5
37	7/78	52	50	45	5	5	1	12		26	4	4	9	16	1		2	7	4		38		1			5	38
Total frequency of occurrence			195	157	10	9	9	12	4	76	15	7	10	18	9	3	3	17	34	1	95	3	10	6	13	56	111
Percent frequency of occurrence			100	81	5	5	5	6	2	39	8	4	5	9	5	2	2	9	17	<1	49	2	5	3	7	29	57

Food of Humpy Shrimp (*Pandalus goniurus*)

Two hundred forty-one *Pandalus goniurus* stomachs were examined; 82% (197 individuals) contained food (Table VI.B.XX; Fig. VI.B.3). The three most frequently observed food items were unidentifiable Crustacea, 28% frequency of occurrence, unidentifiable Polychaeta, 11%; and unidentifiable small clams, 7%. Additionally, decapods, ostracods and amphipods were observed in 7%, 2%, and 2%, respectively, of the stomachs. Other polychaetes included Maldanidae, 4%. The clam, *Nucula tenuis*, was also observed in 5% of the specimens. Other food items included Foraminifera, 8%; Teleostei, 6%; plant material, 5%; and diatoms, 4%. Ten other food categories were infrequently observed (Table VI.B.XX). Humpy shrimp typically fed on a variety of organisms. For example, one shrimp, carapace length 13.3 mm, contained amphipod pieces, decapod fragments, two foraminiferans and shell fragments of *Nucula tenuis* and gastropods.

Unidentifiable organic matter and sediment were observed in 37% and 63% of the stomachs, respectively (Table VI.B.XX). In addition, sediment constituted 62% of the dry weight of the stomach contents so analyzed (Table VI.B.XVII).

Prey frequency of occurrence data for humpy shrimp from Station E1 were examined for differences between males and females. Chi-square analysis of the five most frequent categories revealed no significant differences in frequencies.

Results of the present study suggest that the three pandalids examined are opportunistic foragers or food generalists. The shrimps examined utilized a total of 32 food categories with the most common food items reflecting the foods most available (see Section A). No major differences in the most frequently observed food categories found in stomachs of the three shrimp species were observed, i.e., Crustacea, Polychaeta, Bivalvia, and diatoms in decreasing order of importance. Also, these species all showed evidence of active predation as exhibited by the variety of organisms and the type of remains observed. Additionally, this study demonstrates that pandalid shrimps in lower Cook Inlet feed primarily on the bottom, and suggests that they do a considerable amount of sediment sorting for small prey and detritus. Crow (1977) reported that the principal food of pandalid shrimps in Kachemak Bay was detritus and diatoms. The present report suggests that active predation on infaunal invertebrates is also a common mode of feeding. It is possible that sediment and detritus are ingested inadvertently with prey. The importance of detritus and bacterial carbon associated with the sediment as an additional carbon source for shrimp is unknown. It is thought to be significant for some detrital-feeding organisms (Fenchel and Jorgensen, 1977; Moriarty, 1976; Rieper, 1978). The results of this study indicate that sediment and detritus constitute a significant portion of the stomach contents of the shrimp examined. Hence, the importance of detrital and bacterial carbon as food for pandalid shrimps needs to be investigated. If oil contaminates the subtidal sediments of Kachemak Bay, all three species of shrimps would ingest significant quantities of the pollutant.

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TABLE VI.B.XX

FOOD OF COOK INLET HUMPY SHRIMP
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	Date month/year	Depth (m)	No. stomachs examined	No. with contents	Diatoms	Plant material	Foraminifera	Polychaeta	Polynoidae	*Lumbrineris* sp.	*Disoma multisetosum*	Maldanidae	Ampharetidae	Terebellidae	Sabellidae	Serpulidae	Gastropoda	Bivalvia	*Nucula tenuis*	*Yoldia* sp.	Crustacea	Ostracoda	Amphipoda	Decapoda	Enchinodermata	Teleost	Unid. Organic material	Sediment
					PREY ITEMS																							
E-1	3/78	49	48	43	2	1	6	8			3	1	4	2	1	1	1	2	2		19		2	5		8	12	32
37	3/78	50	48	42	1	7	2	4								2			1		19					4	25	30
N-2	3/78	27	50	30		1	1											4	2	1	3	6			1	1	14	27
62	3/78	26	41	30			2		4								1				7						13	16
62A	3/78	19	30	29	3			7	1	2		5			1		3	7	3		10		3	2		1	12	27
62A #2	3/78	19	24	23	4	2		3		1		3					1	3	4		9		1	10	1		13	22
Total frequency			241	197	10	13	20	26	1	3	3	9	4	2	2	3	6	16	12	1	67	6	6	17	2	14	89	154
Percent frequency of occurrence			100	82	4	5	8	11	1	1	1	4	2	1	1	1	2	7	5	1	28	2	2	7	1	6	37	63

Feeding of Larval Stages of King and Snow Crabs and Pink Shrimp

King crab zoeae

At population densities of 20 prey items per liter, the average number of zooplankton prey consumed by *Paralithodes camtschatica* zoeae was 0.8 per day with a range of 0 to 1 organisms (Tables VI.B.XXI-VI.B.XXII). When prey numbers were doubled, consumption increased significantly (P = 0.95) (Table VI.B.XXII; Fig. VI.B.4) to an average of 1.3 copepods per zoea. However, the range, 0 to 2 prey consumed per zoea, indicated that on some days feeding was unsuccessful. At prey population densities of 80 organisms per liter the average number of copepods consumed was 2.6 per day, with a range of 1 to 7. At the highest prey concentration examined, 160 copepods per liter, the average number of copepods eaten was 7.6 with a range of 3 to 12 (Table VI.B.XXII; Fig. VI.B.4). The data suggest that in the test beakers, prey population densities had to be 40 to 80 per liter before all the zoeae were able to capture and consume at least one copepod on a daily basis (Paul *et al.*, 1979b).

In the beaker containing king crab zoeae without prey, the first mortality occurred on day four, and 100% mortality occurred by day eight. The survival rates to day eleven in the beaker having 20 prey items per liter was 40%. The survival rate to day eleven in each of the remaining beakers was 60%.

The king crab zoeae held at 2°C and fed first at age 12 hours, killed a daily average of 3.8 prey organisms per zoea. Zoeae fed at the same age, but held at 4°C and 6°C, exhibited similar rates of predation, consuming an average of 3.7 and 4.4 crustaceans per day (Fig. VI.B.5). The temperature of the water in the beakers apparently caused no significant (P = 0.95) differences in predation rates of zoeae fed at age 12 hours (Fig. VI.B.5).

The predation rate of the zoeae first fed at age 60 hours and held at 2°C was considerably lower, 1.7 prey per day, than that of their cohorts fed at age 12 hours and zoeae in the other temperature groups fed at age 60 hours (Fig. VI.B.5). The predation rates of zoeae first fed at age 60 hours and kept at 4°C and 6°C, and their cohorts held at the same temperature and fed at age 12 hours were similar (Fig. VI.B.5).

The zoeae starved for 84 hours, 3.5 days, and kept at 2°C and 4°C were generally unable to capture prey; they consumed an average of 0.03 and 0.50 organisms per day respectively (Fig. VI.B.5). Zoeae starved for 84 hours and held at 6°C retained the ability to capture prey. However, their predation rate of 1.2 copepods per day was only one-third that of zoeae starved for 60 hours and also held at 6°C (Fig. VI.B.5).

The correlation coefficient was determined to be -0.860, this indicates a high negative correlation between the number of hours starved and subsequent ability to capture prey. The t-distribution (P = 0.95) was found to be significant (Paul and Paul, in press).

In Cook Inlet, king crab eggs generally hatch from March through June (A. Davis, pers. comm., Alaska Dept. Fish and Game, Homer, Alaska). During this period monthly mean seawater temperatures are likely to range from 2° to 8°C (U.S. Dept. Commerce, 1970). Therefore, it is probable that Cook Inlet king crab zoeae must forage for food during periods when the water temperatures fall within the range of those examined, 2° to 6°C, in this study. The similarity in the predation rates of stage one zoeae fed at age 12 hours and kept at 2°C, 4°C and 6°C (Fig. VI.B.5) indicates that prey availability when the zoeae first begin to feed is more important in determining feeding success than the seawater temperature.

Paralithodes camtschatica exists as a stage one zoea for approximately 7 to 24 days depending on water temperature (Satoe, 1958). Including its four other larval stages, king crab larva remain planktonic for 47 to 84 days (Satoe, 1958). Little is known about the feeding habits of king crab larvae during this planktonic period. Cultured king crab zoeae will eat phytoplankton, but will not survive unless also fed crustaceans (T. Nakanishi, Hokkaido Regional Fisheries Research Labortory, pers. comm., 1979). In the laboratory, king crab zoeae require copepod concentrations of 40 to 80 per liter to feed successfully (Paul *et al.*, 1979b). If prey concentrations are sufficient, they will consume 12 copepods (Paul *et al.*, 1979b) or 25 *Artemia salina* nauplii per day (Nakanishi, 1976). Ishimaru (1936) reported reduced survival in year classes of king crab subjected to predominantly stormy conditions during the planktonic larval period. It is possible that mixing due to storms interferes with the feeding success of these active zoeae.

The results of this study indicate that if the first zoeae of Cook Inlet king crab receive food within 60 hours of hatching, the larvae are capable of capturing crustacean prey if the prey are available at sufficient concentrations. If feeding is delayed an additional 24 hours, their ability to feed on copepods and probably all zooplankters will be impaired, especially if the water temperature is 4°C or less, and their chances for survival will be reduced. The length of the critical period for snow crab and pink shrimp remains undescribed. The survival rate of *Chionoecetes opilio* also declines if they are starved for the first three days of life (Kon, 1971). *Chionoecetes opilio* zoeae are similar in size to king crab, *C. bairdi* and pink shrimp zoeae, and may be found with them in the Bering Sea.

Snow crab zoeae

The average number of copepods consumed by zoeae of *Chionoecetes bairdi* at prey population densities of 20 per liter was 0.5, with a range of 0.0-1.0, per day. The mean number of copepods eaten by zoeae increased significantly (Table VI.B.XXII; Fig. VI.B.6) with prey availability. Thus, at copepod population densities of 40, 80, and 160 per liter, the average number and range of copepods captured by zoeae were 1.3, 2.2, 4.8, and 0.4-1.0, 1.0-4.0, 2.0-7.0, respectively. Copepod concentrations had to equal 80 per liter before both the mean and range indicated all zoeae successfully captured prey each day (Table VI.B.XXII).

The larvae in the beaker with the highest concentration of copepods exhibited no mortality during the experiment. At the other three prey concentrations examined, zoeae suffered 20% mortality. One hundred percent mortality occurred by day eight in the beaker without food.

Pink shrimp zoeae

The results of the experiment on zooplankton prey population density and feeding response with newly hatched *Pandalus borealis* zoeae larvae were similar to those observed for king crab and snow crab zoeae (Fig. VI.B.7). With prey concentrations of 20 and 40 prey items per liter, the average number of prey consumed was 0.7 and 1.5 organisms per day respectively. At both of these prey population densities shrimp larvae were often unsuccessful at capturing prey, and ranges of 0.0 to 1.2 and 0.6 to 2.8 organisms consumed per day occurred, respectively. With a population density of 80 prey per liter the average number of copepods consumed per shrimp larva increased to 2.3 with a range of 1.0 to 4.0. In chambers containing 160 copepods per liter the mean number of copepods eaten by a zoea was 5.3 and the range increased to 2.3 to 9.6 (Table VI.B.XXII; VI.B.7). These results indicate that in the test beakers prey population densities had to average 80 per liter before each shrimp larva was consistently able to capture at least one prey item per day. Like the observations on king and snow crab zoeae, the average daily consumption rates increased significantly (P = 0.95) up to the highest prey concentrations examined (Table VI.B.XXII; Fig. VI.B.7); therefore, it is impossible to determine maximum consumption rates for these decapod larvae from the data.

The *Pandalus borealis* larvae in the beaker without prey had a 40% mortality on day five, and 100% mortality occurred on or by the thirteenth day. In the other test beakers larval shrimp molted successfully and mortality was zero.

Many decapod larvae, including *Chionoecetes* and *Pandalus*, have been reared to settling using *Artemia* as food (Modin and Cox, 1967; Motoh, 1973). In these studies high mortality rates were reported. Bigford (1978) found that, of the combinations tested, a diet of green flagellates, rotifers, and shrimp nauplii produced the best survival to the first stage juvenile in the spider crab, *Libinia emarginata*. In Cook Inlet king crab zoeae stomachs containe diatoms (E. Haynes, National Marine Fisheries Service, Auke Bay, Alaska, pers. comm., 1980). The nutritional adequacy of small crustaceans as a sole source of food for the decapod larvae examined is unknown. Furthermore, it is probable that prey population densities necessary for the zoeae to obtain adequate nutrition exceed those that allow for the capture of a single prey item. Therefore, we believe that mortality rates of the three species of zoeae studied here cannot be accurately related to food density at this time.

Zooplankton population density data are available for Kachemak Bay, one of the major fishing grounds for king crab, snow crab, and pink shrimp in Cook Inlet. Damkaer (1977) reported zooplankton population densities, primarily copepods and cirripede larvae, ranging from 0.2-1.0 per liter during the period when crab zoeae were present in 1976. These mean population densities are considerably lower than the threshold concentration of 40 to 80 zooplankton per liter, necessary for successful daily feeding response of king crab, snow crab, and pink shrimp larvae in the laboratory. It is possible that zooplankton collected by the obliquely towed nets (0.2 to 0.5 mm mesh) used by Damkaer (1977) do not accurately describe the spatial distributions of the zoeae and their prey. In other areas it has been demonstrated that oceanographic conditions and behavioral responses of prey species cause them to disperse or to aggregate. Ellertsen *et al.* (1977) showed that cod larvae feed principally on *Calanus helgolandicus* nauplii which aggregate during vertical migrations and hence exceed concentrations necessary for successful feeding by cod larvae. Similar behavioral mechanisms may occur in crab and shrimp larvae. Studies of the northern anchovy larvae off California suggest that their survival depends on weather and oceanographic conditions which affect the time of appearance and duration of stratified layers of suitably sized food particles (Lasker, 1975, 1978). Ishimaru (1936) reported extensive mortality of king crab zoeae when stormy conditions occurred during the 60 to 80 day planktonic larval period. The results of the OCSEAP study reported here indicate that if mixing from storms or any other phenomenon kept prey population densities below 40 per liter, the zoeae studied could suffer from starvation. It is also possible that phytoplankton are important food for these zoeae, and their requirements for zooplankton prey are met at relatively low prey concentrations. Adequate assessment of prey concentrations and nutritional requirements of the zoeae is necessary when attempting to determine the reasons for recruitment success or failure. Further study should include detailed surveys of nutritional requirements, feeding behavior, and the effect of temperature and salinity on feeding success and survival of zoeae.

TABLE VI.B.XXI

PERCENT OF PREY TYPES, AND THEIR SIZES (MEAN TOTAL LENGTH AND GREATEST WIDTH) FED TO STAGE ONE ZOEAE OF KING CRAB, SNOW CRAB, AND PINK SHRIMP

Prey type	% King crab prey	% Snow crab prey	% Pink shrimp prey	Length (mm)	Width (mm)
Unidentified copepods	24	70	26	0.7	0.2
Pseudocalanus minutus elongatus					
adults	22		8	1.2	0.3
copepodid (IV,V)	40	5	49	1.0	0.2
Acartia clausi	1			1.1	0.4
A. longiremis	1			1.4	0.4
Oithona helgolandica	9	17	5	0.9	0.2
unidentified nauplii	3	8	12	0.5	0.2

TABLE VI.B.XXII

THE AVERAGE DAILY CONSUMPTION OF COPEPODS BY STAGE 1 ZOEAE OF KING CRAB, SNOW CRAB, AND PINK SHRIMP

($\bar{x}$ = mean; sd = standard deviation; se = standard error)

		King Crab		
Prey density	20/ℓ	40/ℓ	80/ℓ	169/ℓ
$\bar{x}$ eaten	0.8	1.3	2.6	7.6
sd	0.9	0.8	1.8	2.8
se	0.2	0.3	0.5	0.9
range	0.0-2.0	0.0-2.3	1.0-7.0	3.0-12.0
		Snow Crab		
$\bar{x}$ eaten	0.5	1.3	2.2	4.8
sd	0.3	0.6	1.1	1.8
se	0.1	0.2	0.4	0.6
range	0.0-1.0	0.4-2.0	1.0-4.0	2.0-7.0
		Pink Shrimp		
$\bar{x}$ eaten	0.7	1.5	2.3	5.3
sd	0.4	0.7	1.2	2.1
se	0.2	0.2	0.4	0.7
range	0.2-1.0	0.6-2.8	1.0-4.0	2.4-9.6

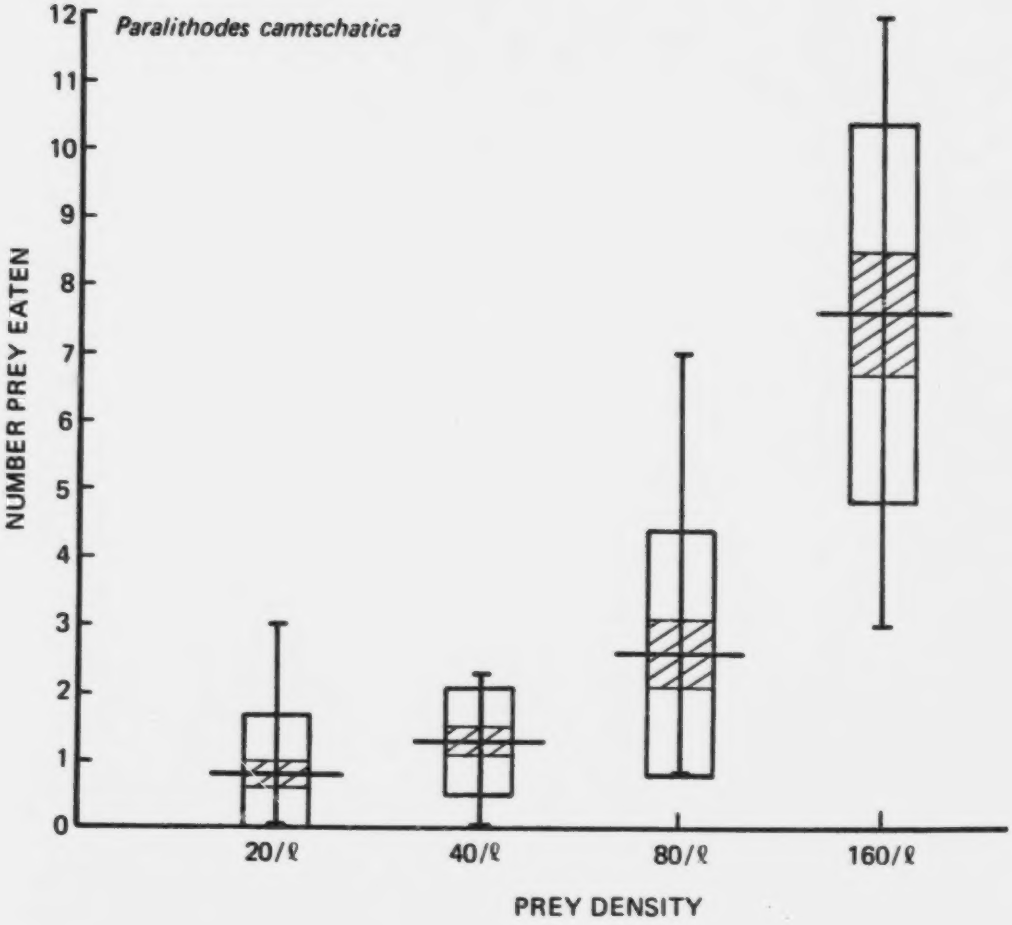

Figure VI.B.4. The number of copepods consumed by king crab zoeae in beakers with different prey concentrations. Horizontal line = mean, vertical line = range, white box = 2 standard deviations, dark box = 2 standard errors of the mean.

6

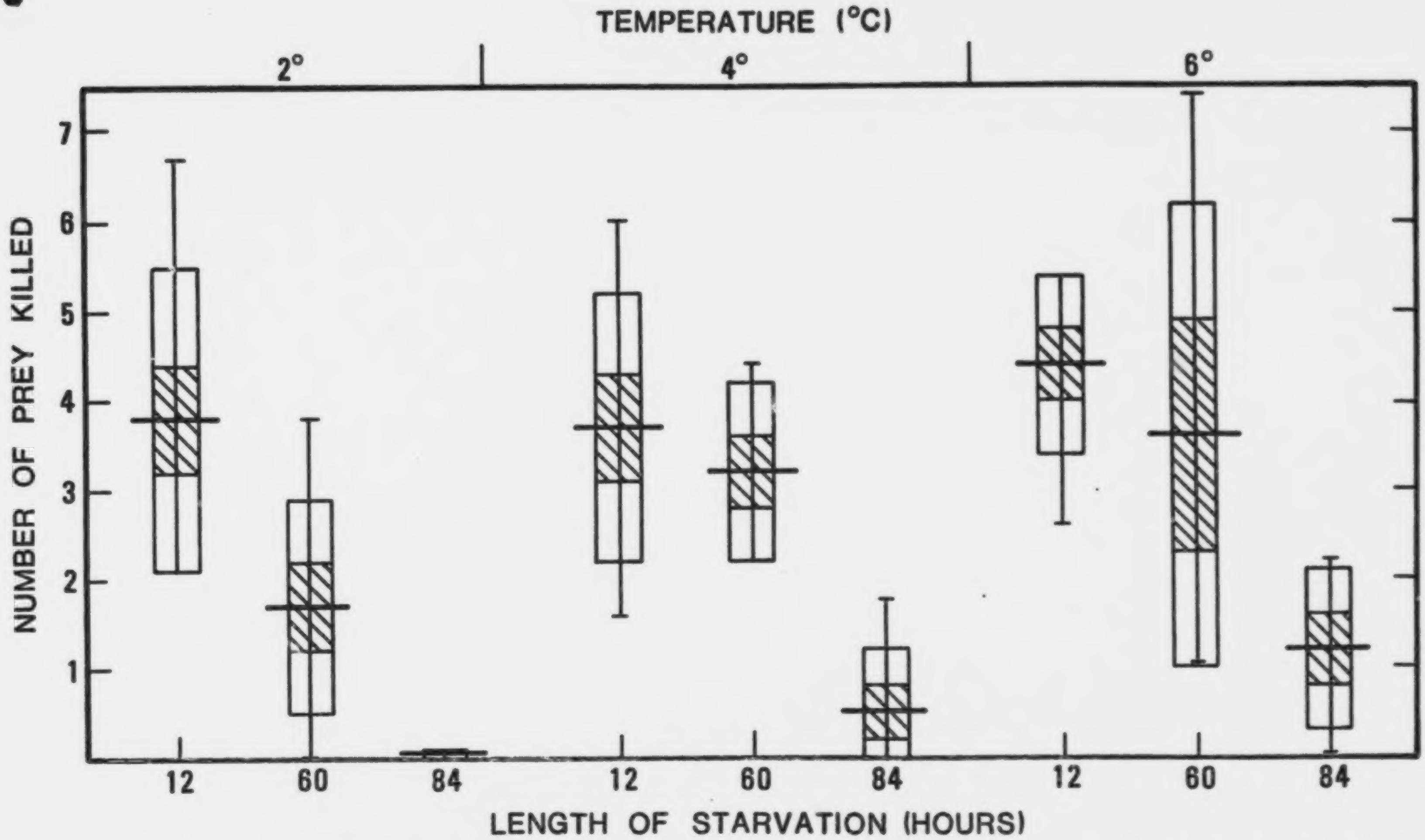

Figure VI.B.5. The number of copepods killed by king crab stage I zoeae starved for 12, 60 and 84 hours and held at 2°, 4° and 6°C. Horizontal line = mean, vertical line = range, white box = 2 standard deviations, dark box = 2 standard errors of the mean.

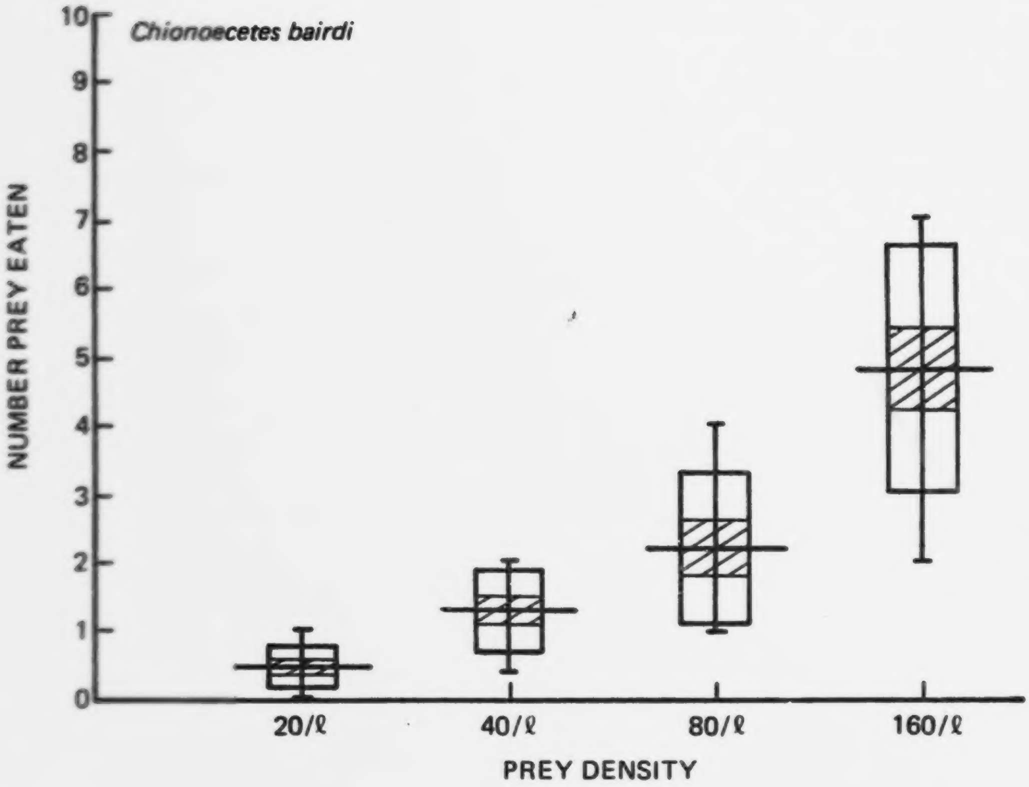

Figure VI.B.6. The number of copepods consumed by snow crab zoeae in beakers with different prey concentrations. Horizontal line = mean, vertical line = range, white box = 2 standard deviations, dark box = 2 standard errors of the mean.

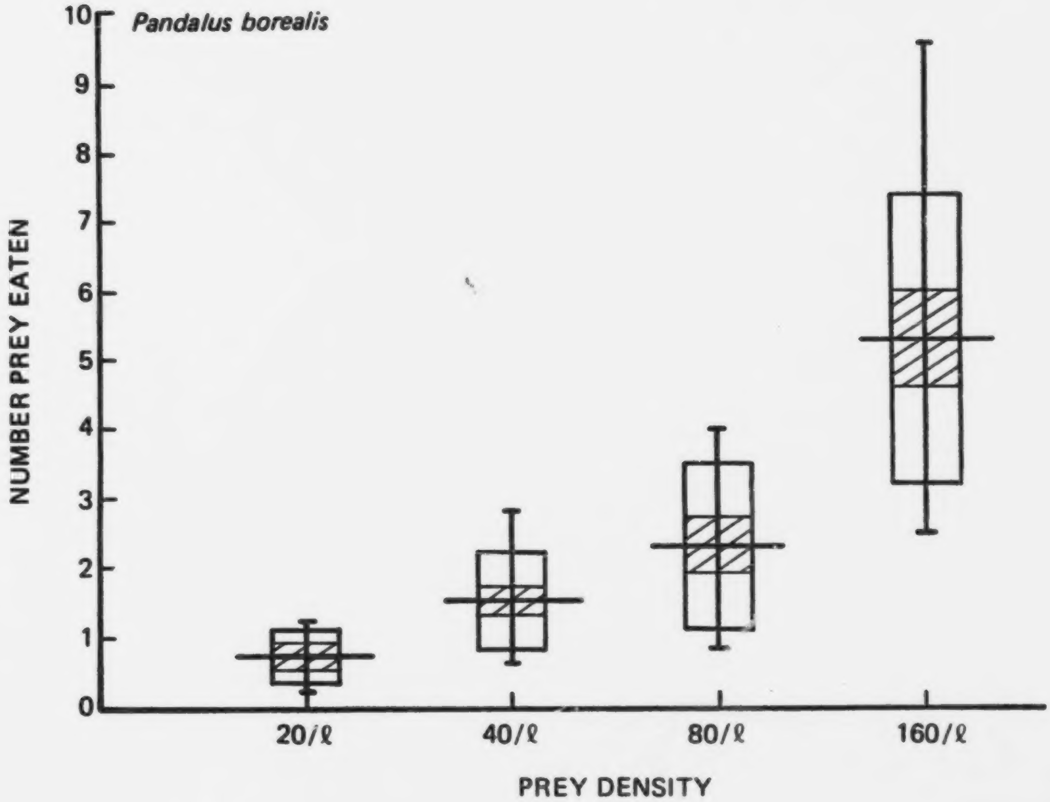

Figure VI.B.7. The number of copepods consumed by pink shrimp zoeae in beakers with different prey concentrations. Horizontal line = mean, vertical line = range, white box = 2 standard deviations, dark box = 2 standard errors of the mean.

Food of *Crangon dalli*

Sediment was found in 71% of the *Crangon dalli* stomachs (Table VI.B.XXIII). *Crangon dalli* stomachs typically contained more than 50% sediment on a dry weight basis (Table VI.B.XXIV). Also present were large numbers of both planktonic and benthic diatoms, and polychaete setae. Only 13% of the observations of polychaete remains in *C. dalli* stomachs were based on the presence of identifiable worm tissue. The remainder of the observations were unattached setae which are commonly present in sediment. (Thus, the importance of polychaetes as food for *C. dalli* are probably overestimated in Table VI.B.XXIV.) Unidentified organic material was observed in 10% of the stomachs.

Parts of unidentified crustaceans were found in 28% of the stomachs, while other crustaceans (ostracods, barnacles, cumaceans, amphipods and other decapods) were found in another 15% of the stomachs. Bivalves were found in 17% of the stomachs.

The high frequency of sediment and unidentified organic matter, possibly detritus, in the stomachs suggests sediment sorting is a prime method of feeding for this organism. Predation on benthic infauna is also important as evidenced by some stomach contents. For example, one stomach contained four intact clams, *Nuculana fossa*, 4 to 6 mm in shell length. See Appendix V for more detailed report on *Crangon* feeding and food requirement.

TABLE VI.B.XXIII

FOOD OF COOK INLET *CRANGON DALLI*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

				PREY ITEMS																	
Station/Date	Depth (m)	No. Stomachs examined	No. with food	Plant material	*Melosira sulcata*	Coscinodiscaceae	*Biddulphia* spp.	*Ditylum brightwellii*	Pennatae	Naviculaceae	*Nitzschia* spp.	Foraminifera	Porifera	Hydrozoa	Rhyncocoela	Nematoda	Unid. Polychaeta	Sigalionidae	Polynoidae	Phyllodocidae	Syllidae
PMEL 1 06/14/78	-	50	48	11	24	10	3	-	7	10	2	12	-	3	1	31	18	4	3	4	-
PMEL 1 07/14/78	-	50	46	9	30	16	1	-	5	15	5	12	-	1	-	8	25	1	11	1	-
PMEL 1 08/15/78	33	50	39	1	10	10	-	-	1	4	-	13	-	-	-	2	20	-	1	-	-
PMEL 7 06/13/78	85	25	16	5	4	4	-	-	2	6	-	5	2	-	-	3	6	-	1	-	-
PMEL 7 07/20/78	85	50	37	4	2	11	-	-	5	16	-	5	7	-	1	6	6	-	1	1	-
PMEL 7 08/14/78	85	48	34	-	-	3	-	-	5	2	-	1	2	-	-	-	4	-	-	-	-
St. 37 05/16/78	-	5	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
St. 37 06/16/78	31	7	7	-	-	-	1	-	1	-	-	-	-	-	-	1	2	-	-	-	-
St. 53 11/07/77	89	46	41	4	14	20	-	-	13	11	-	10	2	3	-	3	13	-	1	-	3
St. 53 06/11/78	89	18	16	-	6	3	1	-	-	1	-	-	-	-	-	2	6	-	-	-	-
St. 53 07/18/78	-	80	62	6	20	13	1	7	-	22	-	3	-	-	-	3	14	1	5	-	-
St. 53 08/19/78	89	50	47	2	12	13	2	-	3	17	-	3	-	1	-	-	7	-	1	-	-
St. 62 11/14/77	27	50	27	3	2	1	-	-	1	2	-	2	1	1	-	-	7	-	4	2	-
St. 62 07/21/78																					
Time (hrs) 0400	27	25	20	0	4	2	1	-	-	5	-	1	-	-	-	-	2	-	-	-	-
0800	27	25	21	-	5	3	-	-	1	5	-	1	-	-	-	-	4	-	1	-	-
1000	27	25	23	-	8	2	-	-	-	3	-	2	-	-	-	-	6	-	1	1	-
1200	27	25	21	-	4	2	-	-	2	5	-	1	-	1	-	-	1	-	1	1	-
1530	27	25	16	-	4	-	-	-	-	3	-	1	-	-	-	-	1	-	2	-	-
1900	27	25	15	-	-	2	1	-	-	3	-	3	-	-	-	-	1	-	-	-	-
2100	27	25	10	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-
St. 62 08/19/78	85	50	42	-	7	3	-	-	3	9	-	-		-	-	-	7	-	1	-	-
St. 62 A tr. 7 03/?/78	-	27	23	-	7	1	-	-	1	4	-	3	1	-	-	-	4	-	-	2	-
St. 62 A tr. 13 03/30/78	-	32	29	4	5	-	-	-	-	4	-	2	-	-	-	-	5	-	2	1	-
St. 62 B 06/11/78	-	50	36	-	4	2	-	-	-	6	-	3	-	1	-	-	3	-	3	-	-
Total Frequency of occurrence	-	863	678	49	173	121	11	7	50	154	7	83	15	11	2	59	163	6	39	13	3
Percent Frequency of Occurrence	-	-	100	6	20	14	1	1	6	18	1	10	2	1	4	7	19	<1	5	2	<1

TABLE VI.B.XXIII

CONTINUED

	PREY ITEMS																				
Station/Date	Nereidae	Nephtyidae	Glyceridae	*Lumbrineris* spp.	Spionidae	Cirratulidae	Flabelligeridae	Scalibregmidae	Capitellidae	Maldanidae	Oweniidae	*Idanthyrsus* sp.	Ampharetidae	Terebellidae	*Terebellides stroemi*	Sabellidae	Unid. Gastropoda	Cephalaspidea	Unid. Bivalvia	*Nucula tenuis*	*Nuculana* spp.
PMEL 1 06/14/78	1	7	-	16	8	-	-	1	-	8	2	-	-	1	-	2	1	2	1	-	1
PMEL 1 07/14/78	-	5	-	14	7	-	-	1	-	18	-	-	-	-	-	2	10	-	6	-	2
PMEL 1 08/15/78	-	3	-	7	6	-	-	-	-	6	-	-	-	-	-	2	3	-	18	-	1
PMEL 7 06/13/78	-	1	-	3	2	-	-	-	-	1	-	-	-	-	-	-	1	-	3	-	1
PMEL 7 07/20/78	-	6	-	8	3	-	-	-	3	2	-	-	1	-	-	10	-	1	13	-	1
PMEL 7 08/14/78	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	4	-	-
St. 37 05/16/78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
St. 37 06/16/78	-	-	-	1	2	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-
St. 53 11/07/77	-	1	-	1	2	-	4	-	-	21	2	-	-	9	3	6	-	-	4	4	2
St. 53 06/11/78	1	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
St. 53 07/18/78	-	1	2	11	14	2	-	3	-	10	-	1	1	1	-	5	-	-	1	-	1
St. 53 08/19/78	-	1	1	7	7	-	-	-	-	10	-	-	-	-	-	-	-	-	4	-	3
St. 62 11/14/77	-	-	-	-	-	-	-	2	-	8	-	-	-	1	-	1	-	-	2	-	-
St. 62 07/21/78																					
Time (hrs) 0400	-	2	-	1	2	-	-	1	-	3	-	-	-	1	2	2	1	1	-	-	-
0800	-	2	-	1	1	-	1	-	-	11	1	1	-	-	-	-	-	2	1	-	-
1000	1	-	-	2	4	-	2	-	1	6	-	-	1	-	-	1	-	2	-	-	-
1200	-	1	-	-	3	-	-	-	-	6	-	-	-	-	-	1	2	-	-	-	-
1530	-	2	-	1	-	-	1	-	-	5	-	-	-	-	-	1	-	2	-	-	-
1900	-	1	-	-	1	-	-	-	-	4	-	1	-	-	-	1	1	1	2	-	-
2100	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-
St. 62 08/19/78	1	-	-	2	1	-	-	-	-	12	-	-	-	-	-	-	-	-	2	-	1
St. 62 A 03/?/78	-	2	-	-	1	-	-	-	-	4	-	-	-	-	1	1	-	-	-	-	3
St. 62 A 03/30/78	-	2	-	-	1	-	-	-	-	5	-	-	-	-	-	-	-	2	-	-	5
St. 62 B 06/11/78	-	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Total Frequency of Occurrence	4	38	3	82	69	3	8	8	6	146	5	3	3	13	6	35	19	14	62	4	21
Percent Frequency of Occurrence	<1	4	<1	10	8	<1	1	1	<1	17	<1	<1	<1	2	<1	4	2	2	7	<1	2

TABLE VI.B.XXIII

CONTINUED

	PREY ITEMS																				
Station/Date	*Yoldia* spp.	*Siliqua* sp.	*Serripes* sp.	*Spisula* sp.	Pycnogonida	Unid. Crustacea	Ostracoda	*Balanus* spp.	Cumacea	*Diastylis* spp.	Unid. Amphipoda	Ampeliscidae	Decapoda	Echinodermata	Chaetognatha	Teleost	Unid. animal tissue	Unid. organic material	Unid. calcareous material	Sediment	(nylon fibers)
PMEL 1 06/14/78	-	-	-	2	-	16	1	-	2	-	1	-	1	1	-	-	15	2	-	44	-
PMEL 1 07/14/78	1	-	-	1	-	21	2	-	-	-	1	-	3	2	-	2	25	2	-	40	-
PMEL 1 08/15/78	1	-	8	-	-	21	5	1	2	1	-	-	-	-	-	-	2	-	1	36	1
PMEL 7 06/13/78	-	-	-	-	-	3	1	-	-	-	-	-	-	1	-	2	3	5	-	13	-
PMEL 7 07/20/78	-	-	-	-	-	8	2	-	-	-	1	-	1	-	-	-	4	9	-	34	2
PMEL 7 08/14/78	-	-	-	-	-	7	-	5	-	-	-	-	3	1	-	-	-	14	-	31	-
St. 37 05/16/78	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
St. 37 06/16/78	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	-	6	-
St. 53 11/07/77	2	-	1	2	-	8	1	-	-	-	-	-	-	2	1	1	9	7	4	32	1
St. 53 06/11/78	-	2	-	-	-	7	-	-	-	-	-	-	-	-	-	1	6	4	-	16	-
St. 53 07/18/78	2	-	-	-	-	13	-	-	1	-	-	1	3	-	-	-	5	8	-	53	1
St. 53 08/19/78	1	-	24	1	1	22	3	3	3	-	7	3	5	-	-	-	3	1	2	45	-
St. 62 11/14/77	-	-	-	1	-	7	1	-	-	-	-	-	-	-	-	-	8	-	2	25	1
St. 62 07/21/78																					
Time (hrs) 0400	-	-	-	-	-	6	-	2	-	-	-	2	2	-	-	-	3	2	-	20	-
0800	-	1	-	-	-	11	-	8	1	-	2	-	1	1	-	-	-	1	-	20	-
1000	-	-	-	-	-	7	1	-	-	1	1	-	2	-	-	1	2	-	-	20	1
1200	-	-	-	-	-	6	-	1	2	1	2	1	-	1	-	-	2	5	-	20	-
1530	-	-	-	-	-	3	-	-	-	1	2	-	1	-	-	-	-	2	3	16	1
1900	-	-	-	-	-	6	-	-	-	-	1	2	1	-	-	-	1	2	-	15	-
2100	-	1	-	-	-	4	-	-	-	-	-	-	-	-	-	-	2	4	-	9	2
St. 62 08/19/78	1	-	7	-	-	13	-	-	-	4	2	5	1	1	-	-	5	7	-	41	2
St. 62 A 03/?/78	-	-	-	-	-	7	-	-	-	-	1	2	2	-	-	-	4	4	-	19	-
St. 62 A 03/30/78	1	-	-	2	-	10	-	-	1	-	2	1	2	-	-	3	5	3	-	29	-
St. 62 B 06/11/78	1	-	-	-	-	30	-	-	-	-	1	-	2	-	-	-	25	2	-	25	-
Total Frequency of Occurrence	10	4	40	9	1	238	17	20	12	8	24	17	32	10	1	10	129	86	12	609	12
Percent Frequency of Occurrence	1	<1	5	1	<1	28	2	2	1	1	3	2	4	1	<1	1	15	10	1	71	1

TABLE VI.B.XXIV

DRY WEIGHTS OF SEDIMENTS IN COOK INLET, *CRANGON* SPP.

Station/Animal	Date	Depth (m)	No. stomachs examined	No. stomachs with contents	Grams dry wt. contents	Sediment dry wt. (dry wt. contents) after KOH, HCL treatment	% contents sediment
40A *Crangon dalli*	10 June 78 14 June 78	33	90	26	.699	.038	5.4%
18 *Crangon dalli*	10 June 78	53	27	15	.269	.019	7.0%
62A *Crangon dalli*	29 March 78	27	123	75	.651	.422	64.8%
#35 *Crangon dalli*	5 May 78	33	32	13	.078	.020	25.6%
#54 *Crangon dalli*	14 May 78	22	91	60	.958	.907	94.7%
PMEL 7 *Crangon dalli*	July	85	51	35	.144	.111	77.1%
PMEL 1 *Crangon* spp.	20 July 78	33	80	51	.209	.139	66.5%
62A *Crangon dalli*	31 March 78	27	72	54	.513	.238	46.4%
53 *Crangon* spp.	11 June 78	89	20	13	.123	.091	74.0%
PMEL 7 *Crangon dalli*	14 August 78	85	178	94	.286	.179	63.0%
27 *Crangon dalli*	17 July 78	33	114	57	.423	.298	70.4%
62 *Crangon dalli*	21 July 78	27	75	40	.345	.254	74.0%

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Food of Hermit Crabs

A total of 218 *Pagurus ochotensis* stomachs were examined, and 21 different prey types were found in their stomachs (Table VI.B.XXV). The most frequently occurring food was barnacles, in 23% of the stomachs; Foraminifera, 21%; plant material, 21%, and young clams of the genus *Spisula*, 17%. The clam, *Nucula tenuis*, occurred in 10% of the stomachs. Polychaetes as well as species of hermit crabs were both observed in 7% of the stomachs. All other organisms were observed in less than 5% of the stomachs. Sediment was observed in 78% of the stomachs and accounted for 11 to 59% of the dried weight of pooled stomach contents (Table VI.B.XXV).

In 38% of the stomachs of *Pagurus capillatus*, Foraminifera were observed. Plant material occurred in 13% of the stomachs. Barnacles and the clam, *Nucula tenuis*, were found in 6 and 5% of the stomachs respectively. There were 14 additional categories of material identified in the stomachs; however, none of them except sediment, occurred in more than 4% of the stomachs. Sediment occurred in 71% of the stomachs and constituted an average of 26% of the dry weight of stomach contents (Table VI.B.XXVI).

Only 17 *Pagurus aleuticus* were available for examination. Fragments of sympodial Hydrozoa were the most frequently occurring item and were found in 71% of the stomachs. Plant material was observed in 18% of the stomachs. Sediment was observed in 76% of the stomachs, and accounted for 0.4 to 27% of the dry weight of stomach contents (Table VI.B.XXVII).

Hydrozoa and plant material appeared in 22 and 13% of the 32 *Pagurus kennerlyi* stomachs respectively. Unidentified crustaceans and Foraminifera were both observed in 6% of the stomachs. Sediment occurred in 72% of the stomachs and accounted for 20% of the dry weight of stomach contents in the one sample examined for sediment weight (Table VI.B.XXVIII).

The most frequently observed food of the 31 *Pagurus beringanus* examined was other hermit crabs, which occurred in 19% of the stomachs. Other unidentified crustaceans were observed in 16% of the stomachs. Plant material was observed in 13% of the stomachs (Table VI.B.XXIX).

The most frequently occurring food of *Elassochirus tenuimanus* was also other hermit crabs, found in 32% of the stomachs. *Balanus* spp. and other unidentified crustaceans were observed in 15 and 11% of the stomachs, respectively. Plant material was observed in 9% of the stomachs (Table VI.B.XXX).

The hermit crabs, *Pagurus ochotensis*, *P. capillatus*, *P. aleuticus*, and *P. kennerlyi*, all appear to be opportunistic foragers which ingest small organisms acquired by sorting through sediments, and swallow large amounts of sediment in the process. They also browse on hydrozoans, pieces of macroalgae, and sea grass detritus. *Pagurus beringanus* and *Elassochirus tenuimanus* appear to be more active predators consuming primarily smaller hermit crabs and other crustaceans. However, these generalizations are based on a limited number of observations, and need to be reexamined after further sampling. Also, the nutritional importance of bacteria associated with the sediments and detritus ingested by these hermit crabs need to be examined.

No other literature concerning the feeding habits of Alaskan hermit crabs is available. Greenwood (1972) and Orton (1927) examined the mouthparts and feeding behavior of hermit crabs and concluded that detrital feeding utilizing the third maxillipeds to scrape or sieve microscopic food from bottom deposits is the general mode of feeding for these animals. Scavenging and predation are believed to be opportunistic and accessory to detrital feedings. The occurrence of significant amounts of sediment in the stomachs of the common hermit crabs suggests a dependence on sediment/detrital feeding in Cook Inlet.

TABLE VI.B.XXV

FOOD OF COOK INLET *PAGURUS OCHOTENSIS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

				PREY ITEMS																						
Station	Date month/year	No. stomachs examined	No. with food	Foraminifera	Hydrozoa	Bryozoa	Polychaeta	*Solariella* spp.*	Unid. Gastropods	*Nucula tenuis*	*Glycymeris subsoleta*	Mytilidae	*Astarte* sp.	*Spisula polynyma*	*Macoma* spp.	Unid. Bivalves	*Balanus* spp.	Paguridae	Unid. Crustaceans	Ophiuridae	Teleost	Unid. tissue	Plant material	Sediment	Total dry weight stomach contents	% stomach contents digestable in KOH	% stomach contents sediment
5	3/78	10	10				4									2							5	9	0.5	54	27
18	3/78	11	11		1		7	2		2				1	2	1							3	6	0.12	18	59
35	11/77	25	24						1	3					4		14	4	1				6	22	-	-	-
35	7/78	39	36	15	1								2		1		24	1		1			1	33	1.45	81	11
36	5/78	32	30	23	2					3		9			1		3		1			1	6	28	0.58	28	27
40	11/77	41	39	2					2		3			27			2	3	1				11	29	-	-	-
42	3/78	2	2				1																1	1	-	-	-
44	11/77	2	2											1										2	-	-	-
49	5/78	8	7			1	2	2		3				1			3		1				4	6	0.16	41	21
Bluff	11/77	7	6															3						4	-	-	-
53	11/77	8	7						1	5					4		2	3						6	-	-	-
53A	5/78	13	13	3		1		1		1				3	1		1	1			2		4	11	0.11	28	22
62	11/77	8	6																					6	-	-	-
62A	3/78	12	11		1		2	2		5				1		1	1						4	8	0.45	44	22
Total Frequency of Occurence		218	200	46	5	2	16	7	4	22	3	9	2	34	13	4	50	15	4	1	2	1	45	17.7			
Percent Frequency of Occurrence			92	21	2	1	7	3	2	10	1	4	1	16	6	2	23	7	2	0.5	1	0.5	21	78			

*The genus *Margarites* occurs in the area and may be included.

TABLE VI.B.XXVI

FOOD OF COOK INLET, *PAGURUS CAPILLATUS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

				PREY ITEMS																				
Station	Date month/year	No. stomachs examined	No. with food	Foraminifera	Hydrozoa	Bryozoa	Polychaeta	*Solariella* spp.*	Unid. Gastropods	*Nucula tenuis*	*Nuculana fossa*	Mytilidae	*Macoma* spp.	Unid. Bivalves	Ostracoda	*Balanus* spp.	Paguridae	Unid. Crustaceans	Unid. tissue	Plant material	Sediment	Total dry weight (g) stomach contents	% stomach contents digestable in KOH	% stomach contents sediment
18	11/77	4	4	1					1												1	-	-	-
18	3/78	12	12	6			1			2				1						2	10	0.10	99	>1
35	11/77	4	3							2								1			2	-	-	-
35	5/78	8	7	4																1	7	0.06	4	36
35	7/78	16	13	5	1													1			13	0.07	25	26
36	5/78	13	11	4		1						1		1	1						10	0.05	66	23
37	11/77	3	3	3						1	1					2					3	-	-	-
49	5/78	3	3	1																1	3	0.05	13	50
53A	5/78	10	1	5			1			1			1			2			1	1	9	0.06	21	25
56	5/78	13	13	9	1	3	1					1				2			2	4	13	0.08	32	21
62	11/77	13	12	4												1	1	1		1		-	-	-
62A	3/78	13	10	1	2			1		1			1	2				1		4	8	0.07	23	27
Total Frecuency of Occurrence		112	92	43	4	4	3	1	1	6	1	2	2	4	1	7	1	4	3	14	79			
Percent Frequency of occurrence			82	38	4	4	3	1	1	5	1	2	2	4	1	6	1	4	3	13	71			

*The genus *Margarites* occurs in the area and may be included.

TABLE VI.B.XXVII

FOOD OF COOK INLET, *PAGURUS ALEUTICUS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS												
Station	Date month/year	No. stomachs examined	No. with food	Foraminifera	Hydrozoa	Polychaeta	Unid. Crustaceans	Unid. tissue	Plant material	Sediment	Total dry weight (g) stomach contents	% stomach contents digestable in KOH	% stomach contents sediment
El.	3/78	8	8	1	8		1		1	5	0.15	66	0.4
49	5/78	4	4			1		2		4	0.05	0.4	27
56	3/78	5	5	1	4	1	1		2	4	0.06	84	16
Total Frequency of Occurrence		17	17	2	12	2	2	2	3	13			
Percent Frequency of Occurrence			100	12	71	12	12	12	18	76			

TABLE VI.B.XXVIII

FOOD OF COOK INLET, *PAGURUS KENNERLYI*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS											
Station	Date month/year	No. stomachs examined	No. with food	Foraminifera	Hydrozoa	Polychaeta	Unid. Crustaceans	Plant material	Sediment	Total dry weight (g) stomach contents	% stomach contents digestable in KOH	% stomach contents sediment
42	3/78	10	10	1	6		1		9	0.25	40	20
Bluff	11/77	19	13	1				4	13	-	-	-
56A	3/78	3	2		1	1	1		1	-	-	-
Total Frequency of Occurrence		32	25	2	7	1	2	4	23			
Percent Frequency of Occurrence			78	6	22	3	6	13	72			

TABLE VI.B.XXIX

FOOD OF COOK INLET, *PAGURUS BERINGANUS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	Date month/year	No. stomachs examined	No. with food	PREY ITEMS Unid. Crustaceans	*Balanus* spp.	Paguridae	Plant material	Sediment
18		17	15	5		2		6
27		3	3					3
Bluff		1	1			1		
62		10	10		1	3	4	10
Total Frequency of Occurrence		31	29	5	1	6	4	19
Percent Frequency of Occurrence			94	16	3	19	13	61

TABLE VI.B.XXX

FOOD OF COOK INLET, *ELASSOCHIRUS TENUIMANUS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	Date month/year	No. stomachs examined	No. with food	Foraminifera	Hydrozoa	Bryozoa	Polychaeta	*Glycymeris subobsoleta*	*Balanus* spp.	Paguridae	Unid. Crustaceans	Plant material	Sediment	Total dry weight (g) stomach contents	% stomach contents digestable in KOH	% stomach contents sediment
				PREY ITEMS												
18	11/77	2	2							2				-	-	-
35	11/77	2	2						1	1	1			-	-	-
35	5/78	5	5	1		1			3		1	2	4			
35	7/78	5	3	1					1				3			
E1	3/78	5	4				1	1		1	1			0.15	66	0.3
42	3/78	5	3		1					1			1	0.15	66	0.1
44	11/77	2	0													
Bluff	11/77	9	9						1	5	1		5	-	-	-
56A	3/78	2	2							1	1		1	-	-	-
56	5/78	4	4	1					1	3			3	-	-	-
62	3/78	6	6		2	2	1			1		2	1	-	-	-
Total Frequency of Occurrence		47	40	3	3	3	2	1	7	15	5	4	18			
Percent Frequency of Occurrence			85	6	6	6	4	2	15	32	11	9	38			

Food of Other Invertebrates

Food data for small numbers of *Lebbeus groenlandica*, *Pandalus danae*, *Crangon communis*, *C. franciscorum*, *Sclerocrangon boreas*, *Argis dentata*, *Oregonia gracilis*, *Hyas lyratus*, and *Ophiura sarsi* is presented in Tables VI.B.XXXI-VI.B.XXXIX. The data is not discussed because the number of stomachs examined is small.

TABLE VI.B.XXXI

FOOD OF COOK INLET, *LEBBEUS GROENLANDICA*
DATA RECORDED AS FREOUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS													
March 1978 Station 56A	**No. stomachs examined**	**No. with food**	**Bacillario phyceae**	**Foraminifera**	**Parazoa (sponge spicules)**	**Hydrozoa**	**Polychaeta setae**	**Ostracoda**	**Oregonidae**	***Chionoecetes bairdi***	**Unid. Decapoda (crab)**	**Unid. Crustacea**	**Byssal threads**	**Sediment**
Total Frequency of Occurrence	25	25	3	1	12	10	8	1	1	1	10	14	12	8
Percent Frequency of Occurrence		100	12	4	48	40	32	4	4	4	40	56	48	32

TABLE VI.B.XXXII

FOOD OF COOK INLET, *PANDALUS DANAE*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS															
March 1978 Station 56A	**No. stomachs examined**	**No. with food**	**Bacillario phyceae**	**Foraminifera**	**Parazoa (sponge spicules)**	**Hydrozoa**	**Polychaeta setae**	***Lumbrineris* sp.**	**Ostracoda**	***Balanus* sp.**	**Unid. Pandalidae**	**Unid. Decapoda (crab)**	**Unid. Crustacea**	**Byssal threads**	**Teleost scale**	**Sediment**
Total Frequency of Occurrence	24	20	4	5	4	1	10	2	1	1	1	3	10	10	1	15
Percent Frequency of Occurrence		83	17	21	17	4	42	8	4	4	4	12	42	42	4	62

TABLE VI.B.XXXIII

LOWER COOK INLET, *CRANGON COMMUNIS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

					PREY ITEMS															
Station	Date month/year	Depth	No. stomach examined	No. with food	*Melosira sulcata*	Coscinodisceae	Naviculeae	Polychaeta	Phyllodocidae	*Lumbrineris* sp.	Spionidae	*Aricidea* sp.	Capitellidae	Maldanidae	Bivalvia	Crustacea	Ampeliscidae	Unid. animal tissue	Unid. dig. material	Sediment
37	5/78	NA	4	4	1	2	1	2	-	2	4	1	-	-	-	3	-	1	-	4
5	3/78	NA	20	12	-	-	-	1	1	-	-	-	1	1	1	1	1	1	4	9
Total Frequency of Occurrence			24	16	1	2	1	3	1	2	4	1	1	1	1	4	1	1	4	13
Percent Frequency of Occurrence				67	4	8	4	13	4	8	17	4	4	4	4	17	4	4	17	54

TABLE VI.B.XXXIV

FOOD OF COOK INLET *CRANGON FRANCISCORUM*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS				
March 1978 Station	Depth	No. stomachs examined	No. with food	Crustacea	Crangonidae
62A	NA	8	2	1	1
Total Frequency of Occurrence			2	1	1
Percent Frequency of Occurrence			25	<1	<1

TABLE VI.B.XXXV

FOOD OF COOK INLET *SCLEROCRANGON BOREAS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS									
May 1978 Station	No. stomachs examined	No. with food	Polychaeta	*Nucula tenuis*	*Yoldia hyperborea*	*Clycymeris subobsoleta*	Unid. Bivalvia	*Balanus* sp.	Unid. Crustaceans	Ophiuroidea
35	11	7			2*	1†	2	1		1
56A	29	4	1	2	1			1	1	
Total Frequency of Occurrence	40	11	1	2	3	1	2	2	1	1
Percent Frequency of Occurrence		28	2	5	8	2	5	5	2	2

*Swallowed intact lengths, 7, 9 mm

†Swallowed intact length, 7 mm

TABLE VI.B.XXXVI

FOOD OF COOK INLET *ARGIS DENTATA*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

May 1978 Station	No. stomachs examined	No. with food	Foraminifera	Polychaeta	*Nuculana fossa**	*Yoldia* sp.	Unid. Bivalvia	*Balanus* sp.	Plant material	Sediment	Total dry weight (g) stomach contents	% stomach contents digestable in KOH	% stomach contents sediment
		PREY ITEMS											
36	36	5		4		1		1		5	0.29	10	38
56	29	13	3	8	1		1	3	5	12	0.21	19	40
Total Frequency of Occurrence	65	18	3	12	1	1	1	4	5	17			
Percent Frequency of Occurrence		28	5	18	2	2	2	6	8	26			

*Clams swallowed intact.

TABLE VI.B.XXXVII

FOOD OF COOK INLET *OREGONIA GRACILIS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

March 1978 Station	No. stomachs examined	No. with food	Foraminifera	Hydrozoa	Bryazoa	Polychaeta	Pycnogonida	Unid. Crustacea	*Balanus* sp.	Paguridae	Ophiuridae	Unid. tissue	Sediment
		PREY ITEMS											
25	4	4					1	1		2		1	
55	30	23	2	3	9	10		2	2	2	2		15
56	8	6		2			1	3		1			1
Total Frequency of Occurrence	42	33	2	5	9	10	1	6	2	5	2	1	16
Percent frequency of Occurrence		79	5	12	21	24	2	14	5	12	5	2	38

TABLE VI.B.XXXVIII

FOOD OF COOK INLET *HYAS LYRATUS*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

March 1978 Station	No. stomachs examined	No. with food	PREY ITEMS Foraminifera	Hydrozoa	*Macoma* sp.	*Clinocardium ciliatum*	Unid. Gastropods	Unid. Crustaceans	*Pandalus* sp.	Paguridae	*Hyas lyratus*
25	4	3	1	1	3	2	1			2	
56	10	7		1				1	1	3	1
Total Frequency of Occurrence	14	10	1	2	3	2	1	1	1	5	1
Percent Frequency of Occurrence		71	7	14	21	14	7	7	7	36	7

TABLE VI.B.XXXIX

FOOD AND SIZE-WEIGHT RELATIONSHIPS OF COOK INLET *OPHIURA SARSI*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

($\bar{x}$ = mean)

November 1978 Station	No. stomachs examined	PREY ITEMS No. with food	Amphipoda	Unid. Crustacea	Unid. animal tissue	Plant material and detritus	Sediment	$\bar{x}$ Disk diameter (mm)	$\bar{x}$ Total dry weight (g)*	$\bar{x}$ Total dry weight	$\bar{x}$ Skeletal dry weight	$\bar{x}$ Total tissue weight	$\bar{x}$ Gonad dry weight†	% Total dry weight tissue	% Total dry weight gonad
Shelikof Strait	54	45	5	3	19	4	36	13.6	3.13	1.343	1.051	0.292	0.043	21.7	3.2
Total Frequency of Occurrence		83	9	5	35	7	67								

*Weight data formalin weight

†Gonads ripe

Food of Selected Fishes

In 1976, a large 400-mesh eastern otter trawl was used to collect invertebrates and in the process several fishes were captured. The stomach contents of selected fishes captured by this trawl were examined for food (Table VI.B.XL). The species most commonly captured and examined were the starry flounder, rock sole, Pacific halibut, and Pacific cod. The three most common prey species of *Platichthys stellatus* (starry flounder) were *Spisula polynyma* (40%), *Crangon dalli* (12%), and *Chionoecetes bairdi* (7%). Rock sole, *Lepidopsetta bilineata*, fed most frequently on amphipods (22%). Halibut, *Hippoglossus stenolepis*, preyed primarily on *C. bairdi* (33%), *Crangon* spp. (23%), and fishes of the genera *Lumpenus* and *Trichodon* (14%). The four most frequently occurring prey types found in Pacific cod, *Gadus macrocephalus*, were young *C. bairdi* (63%), *Crangon* spp. (51%), unidentified fishes and polychaetes 23 and 18% respectively. Small numbers of other species of fishes were also examined (Table VI.B.XL). An additional trawl survey in 1978 provided additional data on the food of fishes. The primary prey of pollock, *Theragra chalcogramma* were Crangonidae (31%) and *Pandalus goniurus* (8%) (see Table VI.B.XLI). The flathead sole, *Hippoglossoides elassodon*, fed on Crangonidae (16%), *C. bairdi* (9%) and *Pandalus borealis* (8%) (Table VI.B.XLII). Yellowfin sole, *Limanda aspera*, fed on *S. polynyma* (57%) and *Macoma* spp. (5%) (Table VI.B.XLIII). The food of other species captured in small numbers is presented in Table VI.B.XLIV).

TABLE VI.B.XL

PERCENT FREQUENCY OF OCCURRENCE OF STOMACH CONTENTS OF SELECTED FISHES FROM LOWER COOK INLET, OCTOBER 1976

Numbers in Parenthesis Indicate the Number of a Specific Predator Containing that Prey

Fishes		% Frequency of Occurrence
Lepidopsetta bilineata (rock sole)		
Stomachs examined:	53	
Stomachs with food:	18	34.0
Stomach contents:	Unidentified Amphipoda (12)	22.6
	Unidentified Crustacea (2)	3.8
	Unidentified Nudibranch (1)	1.9
	Spisula polynyma (1)	1.9
	Crangon dalli (1)	1.9
	Unidentified Pelecypoda (1)	1.9
	Unidentified remains (1)	1.9
Hippoglossus stenolepis (Pacific halibut)		
Stomachs examined:	52	
Stomachs with food:	48	92.3
Stomach contents:	Unidentified fish (17)	32.7
	Chionoecetes bairdi (17)	32.7
	Lumpenus sagitta (7)	13.5
	Trichodon trichodon (7)	13.5
	Crangon dalli (7)	13.5
	Unidentified Crangonidae (5)	9.6
	Pandalus goniurus (4)	7.7
	Cancer magister (4)	7.7
	Pagurus ochotensis (3)	5.8
	Pandalus hypsinotus (2)	3.8
	Unidentified Cottidae (2)	3.8
	Serripes groenlandicus (1)	1.9
	Unidentified Octopus (1)	1.9
	Anonyx sp. (1)	1.9
	Unidentified Amphipoda (1)	1.9
	Pinnixa sp. (1)	1.9
	Pandalopsis dispar (1)	1.9
	Unidentified Stichaeidae (1)	1.9
	Unidentified Zoarcidae (1)	1.9
	Microgadus proximus	1.9

TABLE VI.B.XL

CONTINUED

Fishes		% Frequency of Occurrence
Platichthys stellatus (starry flounder)		
Stomachs examined:	55	
Stomachs with food:	31	56.4
Stomach contents:	*Spisula polynyma* (22)	40.0
	Crangon dalli (7)	12.7
	Chionoecetes bairdi (4)	7.3
	Crangon sp. (2)	3.6
	Pandalus borealis (1)	1.8
	Unidentified Pelecypoda (1)	1.8
Hippoglossoides elassodon (flathead sole)		
Stomachs examined:	6	
Stomachs with food:	6	100.0
Stomach contents:	Unidentified Ophiuroidea (3)	50.0
	Unidentified Crangonidae (3)	50.0
	Nuculana fossa (2)	33.4
	Unidentified Polynoidae (1)	16.7
	Macoma sp. (1)	16.7
Atheresthes stomias (turbot)		
Stomachs examined:	10	
Stomachs with food:	0	0
Glyptocephalus zachirus (rex sole)		
Stomachs examined:	6	
Stomachs with food:	0	0
Limanda aspera (yellowfin sole)		
Stomachs examined:	1	
Stomachs with food:	1	100.0
Stomach contents:	Unidentified Pelecypoda	100.0
Gadus macrocephalus (Pacific cod)		
Stomachs examined:	43	
Stomachs with food:	41	95.3
Stomach contents:	*Chionoecetes bairdi* (27)	62.8
	Unidentified Crangonidae (22)	51.1
	Unidentified fishes (10)	23.2
	Unidentified Polychaeta (5)	17.6
	Pandalus borealis (4)	9.3
	Crangon sp. (4)	9.3
	Crangon dalli (2)	4.7
	Unidentified Isopoda (2)	4.7
	Unidentified Amphipoda (2)	4.7
	Pandalus sp. (1)	2.3
	Hyas lyratus (1)	2.3

TABLE VI.B.XL

CONTINUED

Fishes		% Frequency of Occurrence
Gadus macrocephalus (cont'd)		
	Pinnixa sp. (1)	2.3
	Unidentified Paguridae (1)	2.3
	Anonyx sp. (1)	2.3
	Unidentified Crustacea (1)	2.3
	Unidentified Pelecypoda (1)	2.3
	Nuculana fossa (1)	2.3
	Unidentified Pectinidae (1)	2.3
	Unidentified Naticidae egg collar (1)	2.3
	Echiurus echiurus alaskensis (1)	2.3
	Trichodon trichodon (1)	2.3
	Hippoglossoides elassodon (1)	2.3
	Atheresthes stomias (1)	2.3
Theragra chalcogramma (walleye pollock)		
Stomachs examined:	17	
Stomachs with food:	8	47.1
Stomach contents:	Unidentified Crustacea (4)	23.5
	Pandalus borealis (4)	23.5
	Unidentified Crangonidae (1)	5.9
Microgadus proximus (Pacific tomcod)		
Stomachs examined:	12	
Stomachs with food:	11	91.7
Stomach contents:	*Pandalus borealis* (9)	75.0
	Crangon dalli (2)	16.7
	Pagurus ochotensis (1)	8.3
Bathymaster signatus (searcher)		
Stomachs examined:	21	
Stomachs with food:	4	19.1
Stomach contents:	Unidentified Anthozoa (1)	4.8
	Chionoecetes bairdi (1)	4.8
	Unidentified Crangonidae (1)	4.8
	Unidentified Crustacea (1)	4.8
Trichodon trichodon (Pacific sandfish)		
Stomachs examined:	5	
Stomachs with food:	2	40.0
Stomach contents:	*Mallotus villosus* (2)	40.0
Agonus acipenserinus (sturgeon poacher)		
Stomachs examined:	6	
Stomachs with food:	0	0

TABLE VI.B.XL

CONTINUED

Fishes		% Frequency of Occurrence
Lycodes palearis (wattled eelpout)		
Stomachs examined:	2	
Stomachs with food:	2	100.0
Stomach contents:	*Crangon dalli* (2)	100.0
Lycodes sp. (eelpout)		
Stomachs examined:	1	
Stomachs with food:	1	100.0
Stomach contents:	*Macoma* sp.	100.0
	Unidentified Crangonidae	100.0
Myoxocephalus polyacanthocephalus (great sculpin)		
Stomachs examined:	26	
Stomachs with food:	22	84.6
Stomach contents:	*Chionoecetes bairdi* (8)	30.8
	Crangon dalli (6)	23.1
	Hyas lyratus (4)	15.4
	Unidentified fish (2)	7.6
	Unidentified Cyclopteridae (2)	7.6
	Unidentified Cottidae (1)	3.8
	Lumpenus sagitta (1)	3.8
	Unidentified shrimp (1)	3.8
	Cancer oregonensis (1)	3.8
	Cancer magister (1)	3.8
	Pagurus ochotensis (1)	3.8
	Oregonia gracilis (1)	3.8
Cottidae (sculpin)		
Stomachs examined:	3	
Stomachs with food:	3	100.0
Stomach contents:	*Chionoecetes bairdi* (3)	100.0
Cyclopteridae (snailfish)		
Stomachs examined:	4	
Stomachs with food:	4	100.0
Stomach contents:	*Crangon dalli* (4)	100.0
Squalus sp. (dogfish shark)		
Stomachs examined:	1	
Stomachs with food:	1	100.0
Stomach contents:	Unidentified fish	100.0
	Unidentified leech	100.0

TABLE VI.B.XLI

FOOD OF COOK INLET POLLOCK, *THERAGRA CHALCOGRAMMA*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	Date month/year	No. stomachs examined	No. with food	Mean standard length (mm)	Polychaeta	Mysidae	Cumacea	Gammaridae	Amphipoda	Euphusiidae	*Pandalus borealis*	*P. goniurus*	*P. hypsinotus*	Unid. Pandalidae	*Crangon dalli*	Unid. Crangonidae	Paguridae	Unid. Zoea	Unid. Crustaceans	*Clupea harangus*	Unid. Teleost
					PREY ITEMS																
37	03/78	39	31	101			6					15	1	2		9			1		1
38	03/78	6	3	98											1	2					
56	03/78	9	9	136	1			3						2		4			5		
56C	03/78	5	5	143	1			3						3		1					
62A	03/78	77	52	115	6			5	1					2	10	11	2		6	2	2
54	05/78	7	7	133						5									1		1
PMEL 1	07/78	2	1	145						1								1			
PMEL 7	07/78	12	12	157		1				2	1			1					5		
37	07/78	2	1	131				1	1	1											
40	07/78	4	1	160		1															
18	08/78	6	6	161		2									1						
35	08/78	6	5	160		1										2					
54	08/78	4	3	172		1										1			1		
Total Frequency of Occurrence		179	136		8	6	6	12	2	9	1	15	1	10	12	30	2	1	19	2	4
Percent Frequency of Occurrence			76		4	3	3	6	1	5	0.5	8	0.5	6	7	17	1	0.5	11	1	2

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TABLE VI.B.XLII

FOOD OF COOK INLET FLATHEAD SOLE, *HIPPOGLOSSOIDES ELASSODON*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

					PREY ITEMS																									
Station	Date month/year	No. stomachs examined	No. with food	Mean standard length (mm)	Foraminifera	Polychaeta	*Solariella* spp.*	*Natica clausa*	Unid. Gastropoda	*Nucula tenuis*	*Nuculana fossa*	*Yoldia* spp.	*Chlamys* sp.	*Balanus* spp.	Amphipoda	Euphausiidae	*Pandalus* spp.	*Pandalus borealis*	*Pandalus goniurus*	*Pandalus hypsinotus*	Unid. Crangonidae	*Crangon dalli*	Unid. Paguridae	*Hyas lyratus*	*Chionoecetes bairdi*	*Cancer* sp.	Unid. Pinnotheridae	Unid. Crustaceans	Ophiuroidea	*Theragra chalcogramma*
36B	05/78	3	3	87			3								1						2	2	7	12					3	
5	06/78	38	31			1		2	1				1		1		1								14	1	3			1
28	06/78	13	8	128		1									1						4	1						1		
37	06/78	7	6	163														6		1										
39	06/78	5	2	133														1										1		
40A	06/78	1	1	145													1													
PMEL 7	07/78	5	4														1	2			1									
PMEL 1	07/78	9	9		1	1						1			1	1					3	1						2		
27	07/78	15	13	150								1		1	1						6	4						1		
37	07/78	6	1	175															1											
40	07/78	6	4	141						1							1				1							2		
18	08/78	22	11	143							2	2			1						3	2						1		
27	08/78	2	1	150																	1							1		
28	08/78	5	3	142																		2						1		
27	08/78	6	4	128																	2							1		
40	08/78	10	9	150		1	1											3										4		
53	08/78	7	4									1			1						2									
Total Frequency of Occurrence		160	114		1	4	4	2	1	1	2	5	1	2	7	1	3	12	1	1	25	12	7	12	14	1	3	17	3	1
Percent Frequency of Occurrence			71		0.6	2	2	1	0.6	0.6	1	3	0.6	1	4	0.6	2	8	0.6	0.6	16	8	4	8	9	0.6	2	11	2	0.6

*The genus *Margarites* occurs in the area and may be included.

TABLE VI.B.XLIII

FOOD OF COOK INLET YELLOWFIN SOLE, *LIMANDA ASPERA*
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

					PREY ITEMS																						
Station	Date month/year	No. stomachs examined	No. with food	Mean standard length (mm)	Foraminifera	Polychaeta	*Natica clausa*	*Neptunea lyrata*	*Nucula tenuis*	*Nuculana fossa*	*Yoldia* spp.	*Glycymeris subsoleta*	*Modiolus modiolus*	*Serripes groenlandicus*	*Spisula polynyma*	*Macoma* spp.	*Tellina nuculoides*	Unid. bivalve	*Balanus* spp.	Amphipoda	*Pandalus* spp.	*Crangon* spp.	*Argis* sp.	Paguridae	Unid. Crustaceans	Ophiuroidea	Teleost
27	11/78	14	7	157				1							1							3	1				1
36B	05/78	3	2	135																		1		1			
56	05/78	1	1	140					1																		1
28	06/78	25	22	198	2	2						1			17				1					1		1	
53	06/78	12	6	177						1					2	2		2							2		
40A	06/78	1	1	185											1												
40	07/78	14	13	214		2			1						9	1	1		1								
41	07/78	1	1	290																	1						
PMEL 1	07/78	13	12	140		1			1	1					9												
27	07/78	89	85	140		1					3		1	3	70	1		1	5	1	1	1					
18	08/78	15	3	172		1	1	1		1	1			1	9	1				1				1			
40	08/78	12	11	206											4	5	1		1					1	1		
27	08/78	12	10	163						1		1			6				1	1				1			
28	08/78	4	4	166											3			1							2		
35	08/78	14	12	161					1	3				1	2	3			8						1		
62A	08/78	4	3	150															2	1							
Total Frequency of Occurrence		234	193		2	7	1	2	4	7	4	2	1	5	133	13	2	4	19	4	2	5	1	5	6	1	2
Percent Frequency of Occurrence			82		1	3	<1	1	2	3	2	1	<1	2	57	5	1	2	8	2	1	2	<1	2	3	<1	1

TABLE VI.B.XLIV

FOOD OF SELECTED COOK INLET FISHES

Species	Station	Month Captured	N	Size Range (mm, SL)	Prey
		1978			
Lycodes brevipes	37	July	15	180-240	*Nuculana fossa*, Crangonidae, Teleost
Lycodopsis pacifica	6	July	1	245	*Chionoecetes bairdi*
Bathymaster signatus	35	May	5	96-150	Crangonidae, Amphipoda
	36B	May	1	170	Crangonidae
	56A	May	2	140-170	Pandalidae, Gammaridae, *Strongylocentrotus* sp.
Anoplopoma fimbria	5	June	4	380-400	*Theragra chalcogramma*, Sipunculida
Agonus acipenserinus	5	July	20	-	Amphipoda
Glytocephalus zachirus	5	July	6	160-290	Amphipoda, Polychaeta
Hyppoglossus stenolepis	54	May	1	165	*Crangon dalli*, Mysidacea
	28	July	1	212	Paguridae, Teleost
	27	July	1	205	*Pagurus ochotensis*, *Agonus* sp.
Microstomus pacificus	5	July	14	280-320	Polychaeta, Amphipoda
Lepidopsetta bilineata	28	June	3	130-230	Polychaeta, *Spisula polynyma*, *Macoma* sp., Amphipoda
	5	July	8	220-300	Polychaeta, Amphipoda, *Hyas lyratus*
	27	July	2	145-225	Polychaeta, *Siliqua patula*, *Spisula polynyma*
	40	July	1	240	*Spisula polynyma*
	41	July	11	180-290	Polychaeta, *Balanus* sp.
	18	August	1	160	*Yoldia* sp.
Platichthys stellatus	54	May	1	390	*Pandalus goniurus*
Psettichthys melanostictus	28	June	3	112-174	Amphipoda
	40A	June	2	160-275	Amphiuroidea, *Lumpenus* sp.
	40	July	13	113-240	*Spisula polynyma*, Amphipoda
	40	August	2	160	*Spisula polynyma*
	41	August	6	140-230	Polychaeta, *Spisula polynyma*, *Balanus* sp.

General Discussion

The results of stomach analysis of Cook Inlet benthic invertebrates indicate that the commercially important crab, shrimp and the fishes examined prey directly on sediment-detrital feeding organisms (Table VI.B.XLV). Furthermore, pink shrimp, coonstripe shrimp and humpy shrimp stomachs contain over 50% sediment on a dry weight basis (Table VI.B.XLV) suggesting that they feed on detritus themselves. Post-larval king crabs and snow crab stomachs also contain sediment, suggesting that these crustaceans ingest large amounts of sediment while feeding (Table VI.B.XLV). Crangonid shrimps, hermit crabs (Table VI.B.XLV), detrital feeding clams and polychaetes, all of which are important prey organisms of these crabs, shrimps, and fishes, also ingest large quantities of sediment. Other prey organisms, such as barnacles and filter feeding clams, probably also inadvertently ingest sediment while feeding on resuspended material. Therefore, if oil were to complex with subtidal sediments in lower Cook Inlet, the commercially important crustaceans and the fishes examined would ingest these hydrocarbons both directly while feeding, and through the consumption of contaminated prey. A similar situation would occur if drilling muds were allowed to settle on feeding areas. Currently, no information on the effect of oil or drilling mud contaminated food on crabs, shrimps or the fishes examined is available.

The most important prey types of the adult stages of the commercially important crabs, shrimps, and fishes examined in Cook Inlet are polychaetes, bivalves, barnacles, crangonid shrimps, and hermit crabs. If oil pollution negatively effected population sizes of these prey organisms, food supplies of the crabs and shrimp species of Cook Inlet would be limited.

The studies on the effect of prey concentration on the feeding success of the zoeae of king crab, snow crab and pink shrimp show that feeding success is impaired if prey concentrations are below 40 per liter. King crab zoeae lose the ability to feed after 3.5 days from hatching if prey concentrations are too low for successful feeding, especially if the water temperature is below 4°C. Survival rates of these larvae are known to be reduced by crude oil pollution (Rice *et al.*, 1976). If oil pollution occurred during a period of low prey availability or negatively affected prey availability, high mortality rates could be expected.

TABLE VI.B.XLV

A SUMMARY OF THE COMMON FOOD AND THE PERCENTAGE OF THE DRY WEIGHT OF THEIR STOMACH CONTENTS THAT ARE SEDIMENT

Organism	Feeding Method	Common Identifiable Food	Percentage Dry Stomach Contents Specimen
Snow crab	predation	bivalves, barnacles, hermit crabs	<16%
King crab adults	predation	bivalves, barnacles, hermit crabs, snails	N.I.
King crab post-larval	predation	crustaceans, Foraminifera, Protozoa	N.A.
Dungeness crab	predation	bivalves, barnacles, amphipods	N.A.
Pink shrimp	sediment sorting and predation	small crustaceans, polychaetes, bivalves	54%
Coonstripe shrimp	sediment sorting and predation	small crustaceans, polychaetes, bivalves	65%
Humpy shrimp	sediment sorting and predation	small crustaceans, polychaetes, bivalves	62%
Crangon dalli	sediment sorting and predation	crustaceans, bivalves	>50%
Argis dentata	sediment sorting and predation	polychaetes, bivalves, plant material	39%
Hermit crabs			
Pagurus ochotensis	sediment sorting and predation	barnacles, Foraminifera, plant material, bivalves	26%
Pagurus aleuticus	sediment sorting and predation	Hydrozoa, plant material	14%
Pagurus kennerlyi	sediment sorting and predation	Hydrozoa, plant material	20%
Pagurus beringanus	sediment sorting and predation	Hermit crabs, other crustaceans, plant material	N.A.
Elassochirus tenuimanus	sediment sorting and predation	Hermit crabs, barnacles, other crustaceans	N.A.
Pollock	predation	*Crangon*, amphipods, euphausids	N.I.
Flathead sole	predation	*Crangon*, snow crabs, *Hyas*, pink shrimps	N.I.
Yellowfin sole	predation	bivalves, barnacles	N.I.

N.A. = not available
N.I. = unknown but probably not important

SECTION C - BIOLOGY OF SIX SELECTED SPECIES OF CLAMS (*NUCULA TENUIS, NUCULANA FOSSA, GLYCYMERIS SUBOBSOLETA, SPISULA POLYNYMA, MACOMA CALCAREA, TELLINA NUCULOIDES*) FROM LOWER COOK INLET

Nucula tenuis

Nucula tenuis was collected at the stations listed in Table VI.C.I and shown in Fig. VI.C.1. There was no apparent gear bias in age sampling of this species, as the age classes were well represented in the collections as shown in age composition (Table VI.C.II). Two hundred and two *N. tenuis* were aged from eleven stations; 16, 18, 27, 28, 33, 37, 39, 49, 53, 54, and 62A. The annual increase in shell length for each of the size classes was typically 0.6 to 1.0 mm (Tables VI.C.II-VI.C.VII; Figs. VI.C.2-VI.C.6). Growth rates were similar at all stations, and varied only slightly from year to year (Figs. VI.C.2-VI.C.4). The integrity of the age classes is suggested by Figs. VI.C.5 and VI.C.6, where it can be observed that none of the standard errors of the mean overlap. The mean shell length at each annular age showed some variation (Figs. VI.C.2-VI.C.4). However, all the values for mean shell lengths at an annulus (Figs. VI.C.2-VI.C.4) did not exceed the standard deviation around that mean annular length by more than 1 mm (Tables VI.C.II-VI.C.VII).

The majority of the specimens examined were between 0 and 4 years of age. However, there was considerable variation in the age composition of the collections (Tables VI.C.II-VI.C.VII). For example, 89% of the *Nucula tenuis* from Station 28 were between 0 and 2 years of age while 100% of the clmas from Station 49 were between 2 and 4 years of age. The oldest and largest *N. tenuis* collected were 7 years of age and 9.7 mm in length, respectively. This species can survive at least 9 years as indicated by data from the Bering Sea (Feder *et al.*, 1980).

Dry weights of the various age classes are available in Table VI.C.VIII. Biomass estimations (dry tissue weight) for each age class were made for *Nucula tenuis* at Station 28. Total *N. tenuis* biomass at Station 28 was estimated at 0.19 g/m^2 (Table VI.C.IX).

Approximately 26% mortality occurred in the first year class of *Nucula tenuis*, this gradually increased to 36% by age 7 (Table VI.C.X);

Fig. VI.C.7). Calculations using the age composition Tables VI.C.II to VI.C.VII indicate that extensive mortality occurred after 4 years of age, 96% of the clams were from 0 to 4 years of age. This species is preyed upon by the large crabs and shrimps of the area (see Section B). No comparable mortality data are available for this species from other regions of the Gulf of Alaska. This bivalve undergoes more extensive mortality in the Bering Sea than in Cook Inlet (Feder *et al.*, 1980). In the former area, 50% mortality occurred by age 5.

Similar growth, size at age (Tables VI.C.II-VI.C.VII; Figs. VI.C.5-VI.C.6) and growth histories (Figs. VI.C.2-VI.C.4) were observed for *Nucula tenuis* from each of the Cook Inlet stations examined. Data appearing in Table VI.C.LXIV compares size at age from three studies: Neiman (1964); Feder *et al.* (1980) and this report. Neiman (1964) reported mean shell lengths of 1.0, 1.5, 3.9, 5.3, 6.9, and 9.3 mm in length for *N. tenuis* from the eastern Bering Sea for age classes 0 to 5, respectively. Feder *et al.* (1980) reported mean shell lengths of 1.4, 2.2, 3.5, 4.8, 6.0, and 7.2 mm from the eastern Bering Sea. These shell lengths compare with 1.7, 2.3, 3.3, 4.3, 5.3, and 6.2 mm for our Cook Inlet specimens; therefore, this clam appears to grow slightly faster in the eastern Bering sea (Table VI.C.LXIV).

TABLE VI.C.I

NUMBER OF CLAMS COLLECTED BY VAN VEEN GRABS (VV) AND PIPE DREDGE (PD) IN LOWER COOK INLET
APRIL (A) AND OCTOBER (O), 1976

Δ Indicates Additional Clams from Various Qualitative Sources

	Nucula tenuis				*Nuculana fossa*					*Glycymeris subobsoleta*					*Spisula polynyma*					*Macoma calcarea*					*Tellina nuculoid*			
	VV		PD		VV		PD		Δ	VV		PD		Δ	VV		PD		Δ	VV		PD		Δ	VV		PD	
Station	A	O	A	O	A	O	A	O		A	O	A	O		A	O	A	O		A	O	A	O		A	O	A	O
3[1]																												
5	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	212[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
7[1]																												
8[1]																												
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
16	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	16	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	-
19[1]																												
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	4
25	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
27	-	-	-	9	2	2	8	-	-	-	-	-	-	1	-	-	-	-	1	5	-	-	18	19	-	-	-	-
28	-	92	-	29	-	144	-	31	4	376	-	-	179	-	-	-	-	-	1	4	348	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-	-	1	1	-	-	-	-	-	7	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	19	77	-	-
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-
33	-	-	-	12	1	1	3	-	-	-	-	-	-	-	-	-	-	-	1	5	-	17	7	-	-	-	-	-
35	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-
37	-	-	-	5	-	-	-	-	191[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1
39	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-
40[1]																												
40A	-	-	-	-	-	-	-	-	-	-	-	-	152	-	-	-	-	-	36[5]	-	-	-	-	-	-	-	-	8
41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	184	43[5]	-	-	-	-	-	-	-	-	8
42	-	-	-	-	-	-	-	-	-	8	-	38	10	-	-	-	-	1	-	-	-	-	-	-	57	-	113	89
44	-	-	-	-	-	-	-	-	-	-	-	44	5	8[4]	-	-	-	-	-	-	-	-	-	-	200	-	-	19
44A[1]																												
45	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
47[1]																												
48[1]																												
49	-	-	14	8	-	-	5	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	11	-	-	-	-	-
53	-	-	1	9	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	4	-	-	-	-	-
54	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-
62A	-	-	-	4	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	31	-	-	-
66[1]																												
70[1]																												
C	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
M	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UOC[1]																												
UW1[1]																												
UW2	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	49	45
DG1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	135[6]	-	-	-	-	-	-	-	-	-
DG2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	119	-	-	-	-	-	-	-	-	-
DG3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	-	-	-
DG4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	-	-	-
SUBTOTALS	0	92	16	94	4	147	16	31	415	384	0	129	357	12	0	0	0	188	378	16	348	17	120	20	314	77	162	175
TOTALS	203				613					882					566					521					728			

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[1] Clams present but not enumerated—see distribution maps (Figs. VI.C.1, VI.C.8, VI.C.18, VI.C.30, VI.C.39, VI.C.51).
[2] Agassiz trawl, October
[3] Try-net, April
[4] Clam dredge, October
[5] Eastern otter trawl, October
[6] All DG stations sampled were obtained by ADF&G via anchor dredge, September 1976.

TABLE VI.C.II

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM ELEVEN LOWER COOK INLET STATIONS (16, 18, 27, 28, 33, 37, 39, 49, 53, 54, and 62A) (See Table VI.C.I and Fig. VI.C.1)

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	30	1.7	0.1	0.04	1.5-1.9
1	55	2.3	0.3	0.07	1.9-2.9
2	44	3.3	0.3	0.08	2.7-3.8
3	34	4.3	0.3	0.12	3.7-4.9
4	30	5.3	0.4	0.15	4.6-6.0
5	7	6.2	0.2	0.21	5.8-6.5
6	0	--	--	--	--
7	2	9.3	0.5	1.02	9.0-9.7
	Total = 202				

TABLE VI.C.III

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM LOWER COOK INLET STATION 18

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	3	3.5	0.3	0.37	3.3-3.8
3	9	4.2	0.4	0.27	3.7-4.9
4	4	5.1	0.4	0.50	4.7-5.7
	Total = 16				

TABLE VI.C.IV

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM LOWER COOK INLET STATION 28

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	30	1.7	0.1	0.04	1.5-1.9
1	52	2.3	0.3	0.07	1.9-2.8
2	26	3.3	0.3	0.11	2.9-3.8
3	8	.2	0.3	0.22	3.8-4.8
4	4	5.6	0.3	0.39	5.3-6.0
5	1	6.3	0.0	0.00	6.3
	Total = 121				

TABLE VI.C.V

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM LOWER COOK INLET STATION 33

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	1	2.9	0.0	0.00	2.9
2	5	3.4	0.3	0.29	3.1-3.7
3	4	4.1	0.3	0.41	3.8-4.5
4	2	5.4	0.6	1.31	5.0-5.9
	Total = 12				

TABLE VI.C.VI

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM LOWER COOK INLET STATION 49

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	5	3.5	0.2	0.24	3.3-3.8
3	7	4.5	0.3	0.27	4.0-4.8
4	10	5.2	0.3	0.22	4.7-5.8
	Total = 22				

TABLE VI.C.VII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM LOWER COOK INLET STATION 53

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	1	3.4	0.0	0.00	3.4
3	3	4.4	0.3	0.47	4.2-4.8
4	5	5.2	0.6	0.58	4.6-5.8
5	1	6.1	0.0	0.00	6.1
	Total = 10				

TABLE VI.C.VIII

AGE AND DRY-WEIGHT RELATIONSHIPS OF COOK INLET *NUCULA TENUIS*

Age	Number of Clams	Total Dry Weight (g)*	$\bar{x}$ Total Dry Weight (g)	Total Shell Weight (g)	Total Dry Tissue Weight (g)	$\bar{x}$ Dry Tissue Weight (g)	% Dry Tissue†
0	25	0.028	0.0011	0.018	0.010	0.00040	35.7
1	25	0.048	0.0019	0.029	0.019	0.00076	39.6
2	25	0.113	0.0045	0.080	0.033	0.00132	29.2
3	25	0.252	0.0101	0.183	0.069	0.00276	27.4
4	25	0.459	0.0184	0.343	0.116	0.00464	25.3
5	20	0.628	0.0314	0.479	0.149	0.00745	23.7

*Total dry weight = total shell weight + total dry tissue weight

†% dry tissue = $\frac{\text{total dry tissue weight}}{\text{total dry weight}} \times 100$

TABLE VI.C.IX

NUCULA TENUIS: BIOMASS ESTIMATIONS PER m^2 AT STATION 28

Age	Number in 6 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	26	52	0.00040	0.02080
1	39	78	0.00076	0.05928
2	18	36	0.00132	0.04752
3	6	12	0.00276	0.03312
4	3	6	0.00464	0.02784
Total dry tissue weight in g(biomass)/m^2				0.18856

*See Table VI.C.VIII

TABLE VI.C.X

THE NUMBER OF *NUCULA TENUIS* AT EACH AGE, AND THE RELATIONSHIP BETWEEN AGE AND NATURAL MORTALITY IN LOWER COOK INLET

Age (t)	Number at Age from Original Data (N)	Number at Age from Curve in Figure VI.C.7*	Natural Mortality % from Curve in Figure VI.C.7*	Mortality Coefficient (z)
0	30	-	-	-
1	55	53	26	.3067
2	44	39	28	.3314
3	34	28	29	.3365
4	30	20	30	.3567
5	7	14	36	.4420
6	0	9	44	.5878
7	2	5		

*Based on the technique of Gruffydd (1974) in which the number at age from the curve for one-year old clams is estimated. All other numbers at age are calculated using the following expression:

$N_{t+1} = N_t \cdot e^{-z(t)}$; where

N = number of clams
z = mortality coefficient
t = time
t + 1 = time at the next year
e = 2.718

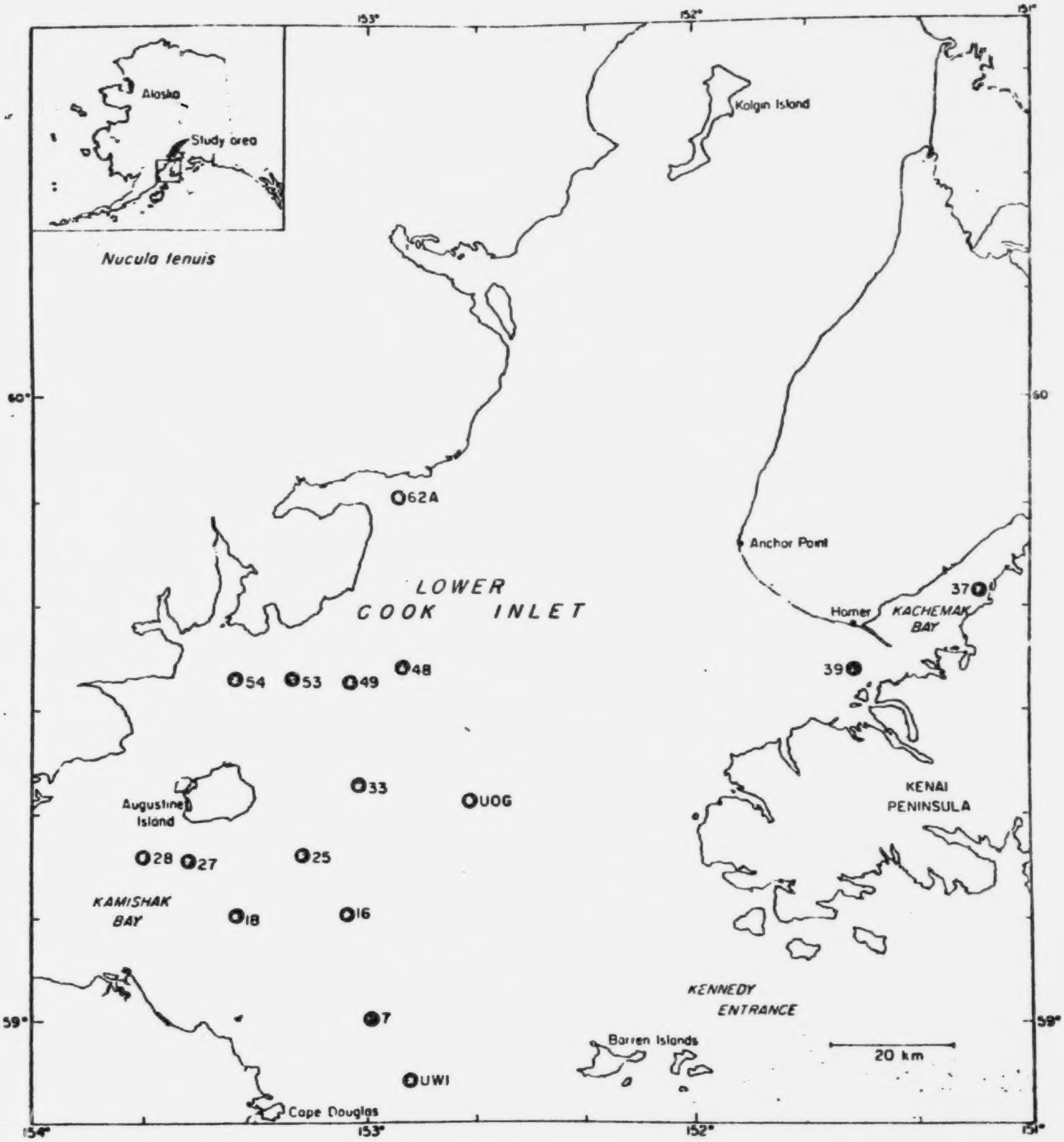

153°
152°
151°
154°
60°
59°
Alaska
Study area
Nucula tenuis
Kalgin Island
Anchor Point
Homer
KACHEMAK BAY
37
39
62A
LOWER COOK INLET
54
53
49
48
33
UOG
Augustine Island
28
27
25
KAMISHAK BAY
18
16
KENNEDY ENTRANCE
KENAI PENINSULA
7
Barren Islands
20 km
UWI
Cape Douglas

Figure VI.C.1. Distribution of all *Nucula tenuis* collected by van Veen grab and pipe dredge from lower Cook Inlet stations.

All Stations (Cook Inlet) *Nucula tenuis*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	Number in Age Class
1	2.3							55
2	2.4	3.4						44
3	2.4	3.4	4.3					34
4	2.3	3.4	4.4	5.3				30
5	2.5	3.5	4.4	5.3	6.2			7
6								0
7	2.6	3.5	4.8	6.1	7.0	8.4	9.4	2
	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION							172

* M S L = Mean Shell Length, mm

Figure VI.C.2. Growth history of *Nucula tenuis* from eleven stations in Cook Inlet; 16, 18, 27, 28, 33, 37, 39, 49, 53, 54, and 62A.

Station 28 (Cook Inlet) *Nucula tenuis*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	Number in Age Class
1	2.3					52
2	2.4	3.3				26
3	2.4	3.4	4.2			8
4	2.3	3.3	4.5	5.6		4
5	2.7	4.0	4.6	5.7	6.3	1
	1972	1973	1974	1975	1976	Total
	* Y A F					91

* M S L = Mean Shell Length, mm

* Y A F = Year of Annulus Formation

Figure VI.C.3. Growth history of *Nucula tenuis* from Cook Inlet Station 28.

Station 49 (Cook Inlet) *Nucula tenuis*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	Number in Age Class
1					0
2	2.3	3.5			5
3	2.3	3.3	4.5		7
4	2.3	3.5	4.3	5.3	10
	1973	1974	1975	1976	Total
	*Y A F				22

* M S L = Mean Shell Length, mm

* Y A F = Year of Annulus Formation

Figure VI.C.4. Growth history of *Nucula tenuis* from Cook Inlet Station 49.

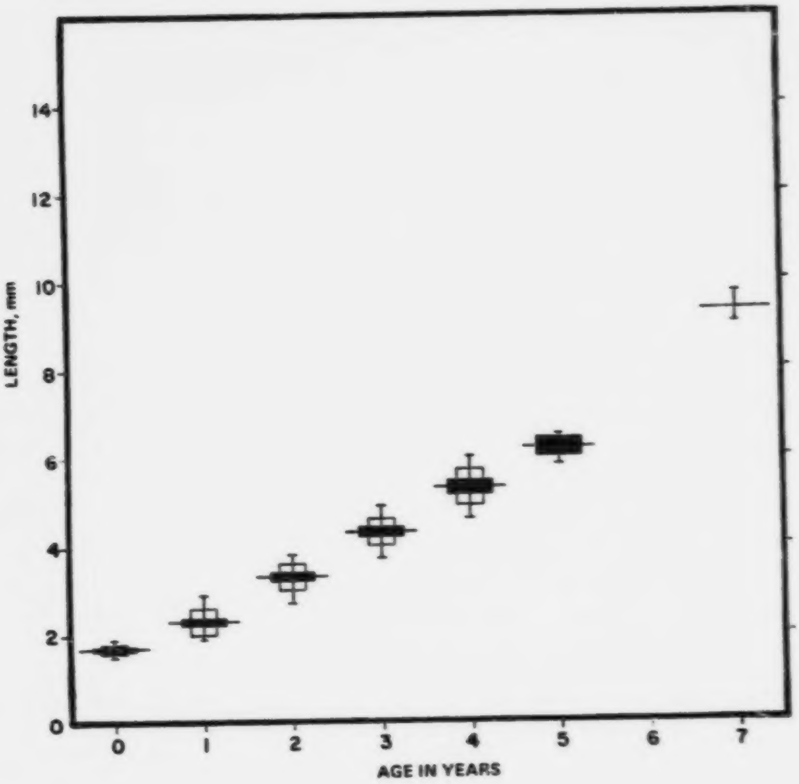


Figure VI.C.5. Growth curve for *Nucula tenuis* from eleven stations in Cook Inlet; 16, 18, 27, 28, 33, 37, 39, 49, 53., 54, and 62A. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

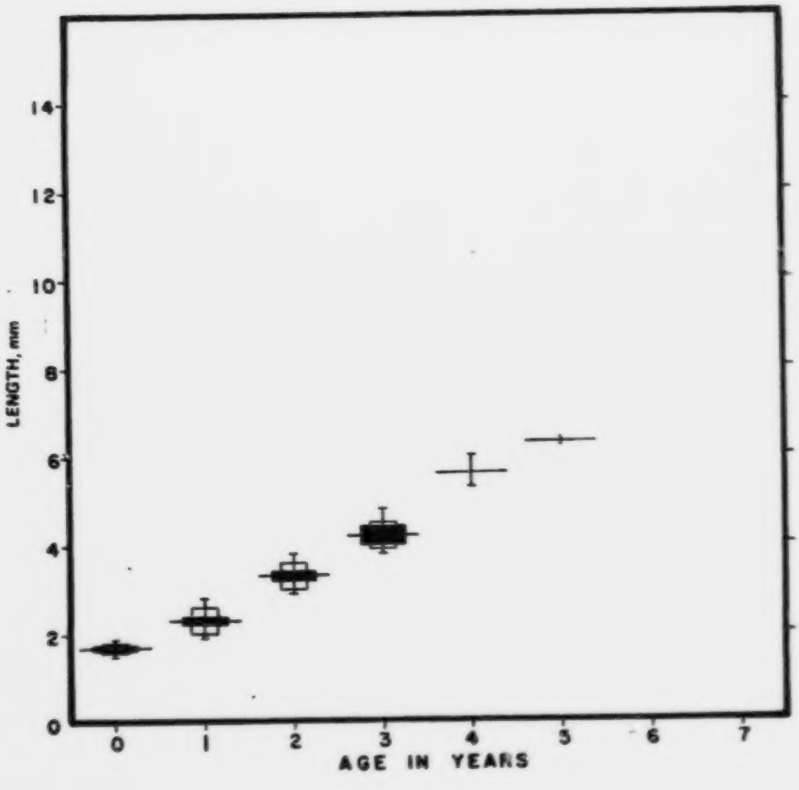


Figure VI.C.6. Growth curve for *Nucula tenuis* from Cook Inlet Station 28. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

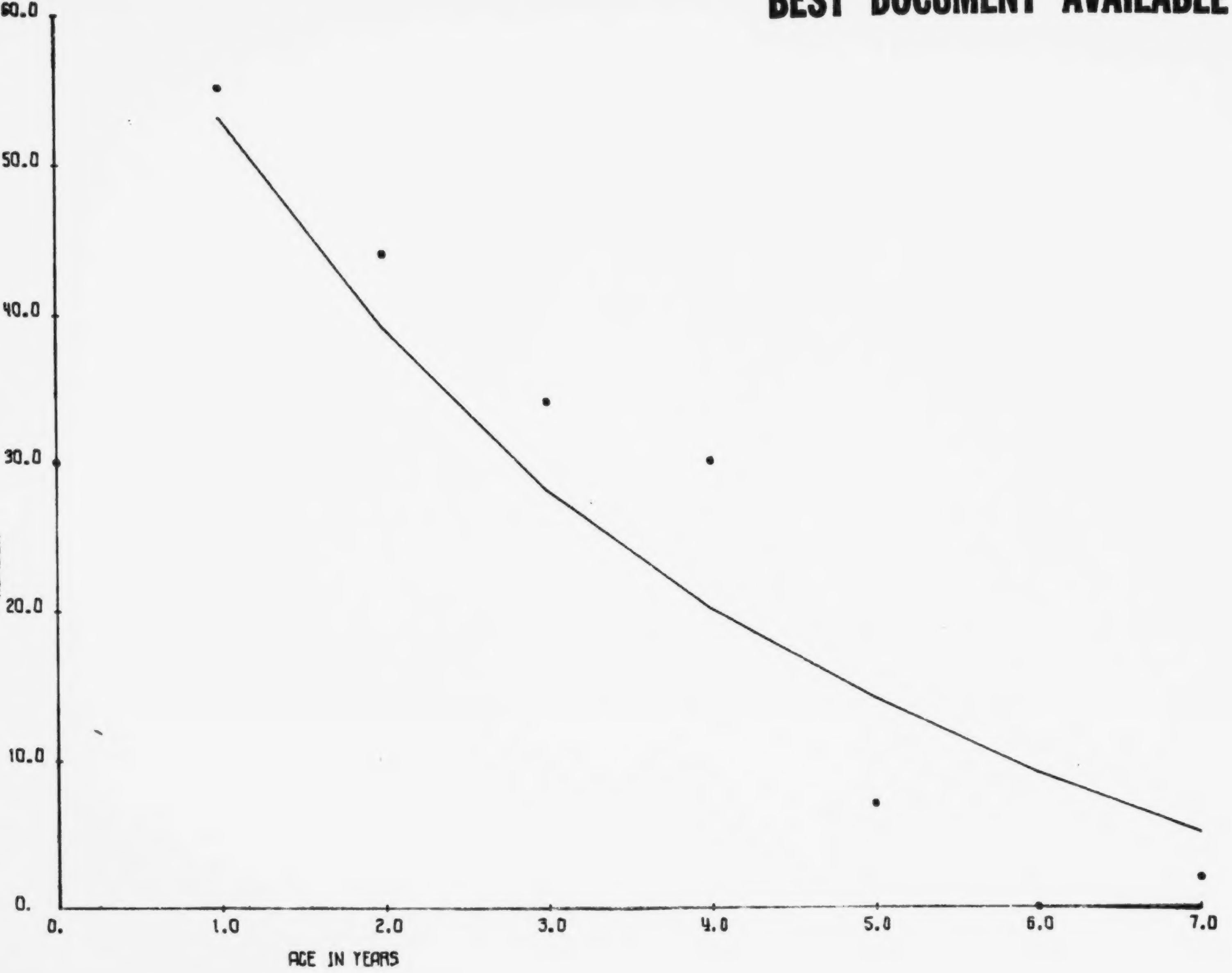


Figure VI.C.7. Graph of abundance vs. age for *Nucula tenuis* in Cook Inlet.

Nuculana fossa

Nuculana fossa was collected at the stations listed in Table VI.C.I and shown in Fig. VI.C.8. There was no apparent gear bias in age sampling of this species, as all age classes were well represented in the collections as shown in age composition Table VI.C.XI. Six hundred and three *N. fossa* were aged from eight stations; 5, 6, 27, 28, 33, 37, 49, and 54. The annual increase in shell length for each of the size classes in Cook Inlet was typically 1 to 3 mm (Tables VI.C.XI-VI.C.XIV; Figs. VI.C.9-VI.C.16). Growth rates were similar at all stations, and varied only slightly from year to year (Figs. VI.C.9-VI.C.12). The integrity of the age classes is suggested by Figs. VI.C.13-VI.C.16 where it can be observed that none of the standard errors of the mean overlap. The mean shell length at each annular age showed some variation (Figs. VI.C.9-VI.C.12). However, 94 of the 97 values for mean shell lengths at an annulus (Figs. VI.C.9-VI.C.12) did not exceed the standard deviation around that mean annular length by more than 1.0 mm (Tables VI.C.XI-VI.C.XIV).

The majority of the 603 specimens examined were between 0 and 6 years of age. However, there was considerable variation in the age composition of the collections (Tables VI.C.XI-VI.C.XIV). For example, 93% of the *Nuculana fossa* from Station 6 were between 3 and 6 years of age, while 67% of the clams from Station 28 were in the 0 age class. The oldest and largest *N. fossa* collected were 7 years of age and 19.5 mm in length, respectively. This species can survive at least 9 years as indicated by data form the Bering Sea (Feder *et al.*, 1980).

Dry weights of the various age classes are available in Table VI.C.XV. Biomass estimations (dry tissue weight) for each age class were made for *Nuculana fossa* at Stations 5, 27, 28, and 33 (Tables VI.C.XVI-VI.C.XIX). Total biomass estimations for these stations ranged from 0.002 to 0.49 g/m^2 (Tables VI.C.XVI-VI.C.XIX).

Approximately 14% mortality occurred in the zero year class of *Nuculana fossa*, this gradually increased to 29% by age 6 (Table VI.C.XX; Fig. VI.C.17). Calculations using the age composition (Tables VI.C.XI-VI.C.XIV) indicate that extensive mortality occurred after 6 years of age, 99% of the clams were between 0 and 6 years of age. The mortality curve (Fig. VI.C.17) and age composition (Table VI.C.XI) of the *N. fossa* collection indicates that this species has years when recruitment is considerably more successful than other years. The relatively high number of 5-year-old clams compared to later year classes best illustrates this trend. Therefore, the mortality calculations, which are based on the assumption that annual recruitment is stable throughout a large area, for this species may be inaccurate. Further collections are necessary to validate these calculations. *Nuculana fossa* are preyed upon by large crabs, especially king crab (see Section B). No comparable mortality data are available for this species from other regions of the Gulf of Alaska. This bivalve undergoes similar mortality in the Bering Sea as in Cook Inlet (Feder *et al.*, 1980). In the former area, 50% mortality occurred by age 6; Bering Sea king and snow crabs also prey on *N. fossa*.

Similar growth, size at age (Tables VI.C.XI-VI.C.XIV; Figs. VI.C.13-VI.C.16), and growth histories (Figs. VI.C.9-VI.C.12) were observed for *Nuculana fossa* from each of the Cook Inlet stations examined. Data appearing in Table VI.C.LXIV compares size at age from three studies; Neiman (1964), Feder *et al.* (1980) and this report. Neiman (1964) reported mean shell lengths of 1.3, 4.4, 6.8, 9.1, 12.4, and 16.1 mm for *N. fossa* (called *Leda pernula* by the author; see Abbott, 1974) from the eastern Bering Sea for age classes 0 through 5, respectively. Feder *et al.* (1980) reported mean shell lenghths of 2.5, 4.0, 6.0, 8.6, 10.9, and 12.8 mm from the eastern Bering Sea. These shell lengths compare with 2.1, 3.7, 6.7, 9.0, 10.9, and 12.9 mm for our Cook Inlet specimens; therefore, this clam appears to grow slightly faster in the eastern Bering Sea (Table VI.C.LXIV).

TABLE VI.C.XI

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM EIGHT LOWER COOK INLET STATIONS (5, 6, 27, 28, 33, 37, 49, 54) WHERE THE CLAMS WERE COLLECTED (See Fig. VI.C.15)

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	119	2.1	0.3	0.05	1.5-3.1
1	67	3.7	0.7	0.17	2.6-5.5
2	97	6.7	0.8	0.16	4.7-8.1
3	88	9.0	0.9	0.19	7.1-11.2
4	60	10.9	0.9	0.23	9.0-12.8
5	106	12.9	0.7	0.13	11.3-15.0
6	60	14.0	0.8	0.20	12.4-15.7
7	6	16.2	1.9	1.75	14.5-19.5
	Total = 603				

TABLE VI.C.XII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM LOWER COOK INLET STATION 6

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	11	6.2	0.8	0.52	4.7-7.2
3	34	9.0	0.8	0.27	7.4-10.4
4	39	10.8	0.8	0.25	9.6-12.6
5	77	12.8	0.6	0.13	11.5-15.0
6	48	13.8	0.7	0.20	12.4-15.1
7	3	14.9	0.6	0.88	14.5-15.6
	Total = 212				

TABLE VI.C.XIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM LOWER COOK INLET STATION 28

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	119	2.1	0.3	0.05	1.5-3.1
1	32	3.6	0.8	0.28	2.6-5.5
2	11	6.7	0.9	0.59	5.3-7.8
3	12	7.9	0.8	0.50	7.1-9.7
4	3	9.5	0.5	0.73	9.0-10.0
5	2	12.1	1.1	2.27	11.3-12.9
	Total = 179				

TABLE VI.C.XIV

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM LOWER COOK INLET STATION 37

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	26	3.6	0.6	0.25	2.8-4.7
2	73	6.7	0.8	0.18	4.8-8.1
3	34	9.3	0.8	0.27	8.0-11.2
4	18	11.4	0.6	0.30	10.0-12.8
5	26	13.4	0.8	0.33	11.6-14.7
6	12	15.0	0.6	0.37	14.0-15.7
7	2	18.3	1.8	3.72	17.0-19.5
	Total = 191				

TABLE VI.C.XV

AGE AND DRY-WEIGHT RELATIONSHIPS OF COOK INLET *NUCULANA FOSSA*

Age	Number of Clams	Total Dry Weight (g)*	$\bar{x}$ Total Dry Weight (g)	Total Shell Weight (g)	Total Dry Tissue Weight (g)	$\bar{x}$ Dry Tissue Weight (g)	% Dry Tissue†
0	13	0.034	0.0026	0.026	0.008	0.00060	23.5
1	25	0.197	0.0079	0.172	0.025	0.00100	12.7
2	6	0.149	0.0250	0.118	0.031	0.00517	20.8
3	17	0.946	0.0556	0.842	0.104	0.00610	11.0
4	4	0.453	0.1130	0.390	0.063	0.01575	13.9
5	3	0.519	0.1730	0.462	0.057	0.01900	11.0
6	2	0.491	0.2455	0.445	0.046	0.02300	9.4
7	2	0.875	0.4375	0.778	0.097	0.04850	11.1

*Total dry weight = total shell weight + total dry tissue weight

†% dry tissue = $\frac{\text{total dry tissue weight}}{\text{total dry weight}}$ x 100

TABLE VI.C.XVI

NUCULANA FOSSA: BIOMASS ESTIMATIONS PER m^2 AT STATION 5

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.00060	0
1	0	0	0.00100	0
2	0	0	0.00517	0
3	1	2	0.00610	0.0122
Total dry tissue weight in g(biomass)/m^2				0.0122

*See Table VI.C.XV

TABLE VI.C.XVII

NUCULANA FOSSA: BIOMASS ESTIMATIONS PER m^2 AT STATION 27

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.00060	0
1	1	2	0.00100	0.020
2	0	0	0.00517	0
3	0	0	0.00610	0
4	0	0	0.01575	0
5	1	2	0.01900	0.0380
Total dry tissue weight in g(biomass)/m^2				0.0400

*See Table VI.C.XV

TABLE VI.C.XVIII

NUCULANA FOSSA: BIOMASS ESTIMATIONS PER m^2 AT STATION 28

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	100	200	0.00060	0.1200
1	24	48	0.00100	0.0480
2	8	16	0.00517	0.0827
3	8	16	0.00610	0.0976
4	2	4	0.01575	0.0630
5	2	4	0.01900	0.0760
Total dry tissue weight in g(biomass)/m^2				0.4873

*See Table VI.C.XV

TABLE VI.C.XIX

NUCULANA FOSSA: BIOMASS ESTIMATIONS PER m^2 AT STATION 33

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.00060	0
1	1	2	0.00100	0.002
Total dry tissue weight in g(biomass)/m^2				0.002

*See Table VI.C.XV

TABLE VI.C.XX

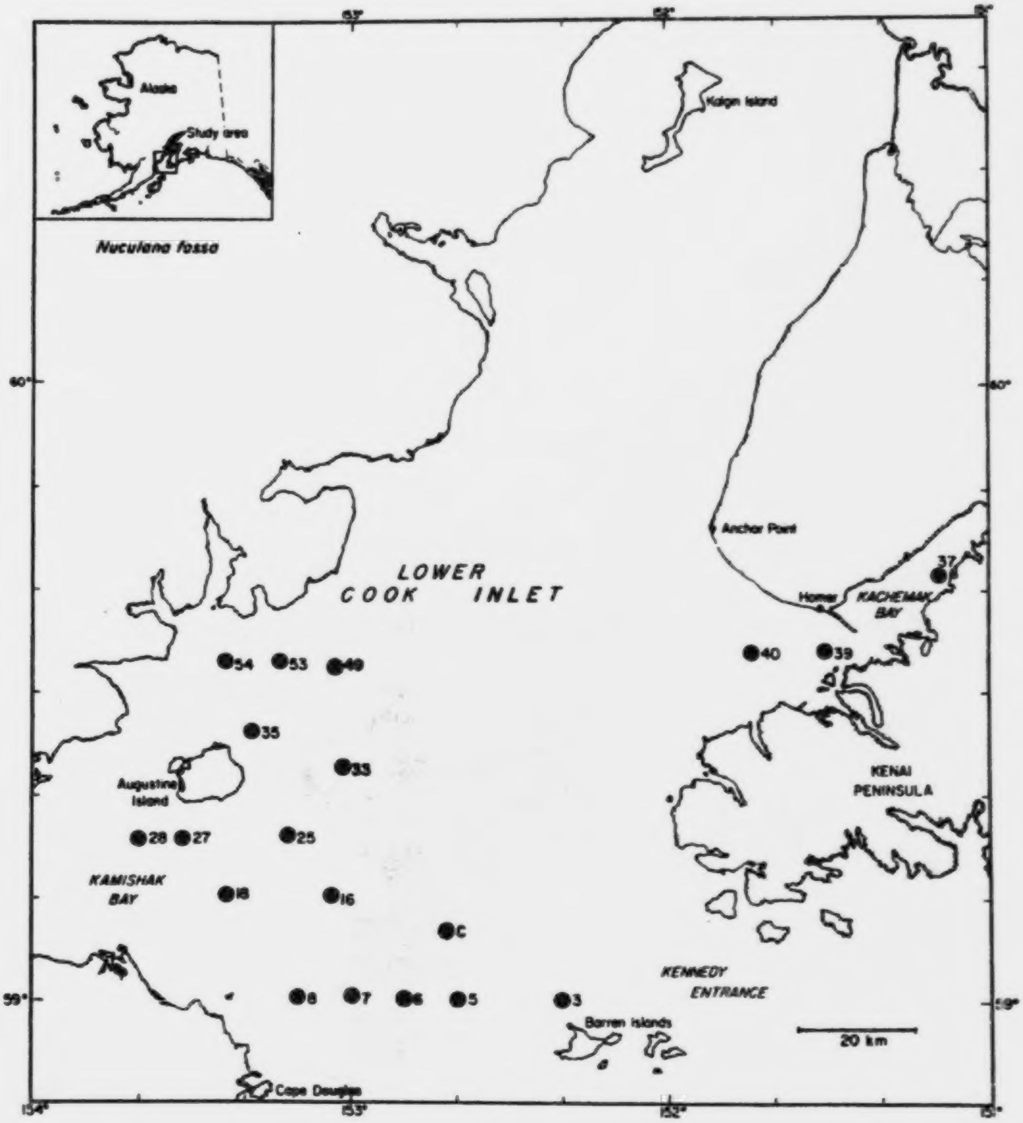
THE NUMBER OF *NUCULANA FOSSA* AT EACH AGE, AND THE RELATIONSHIP BETWEEN AGE AND NATURAL MORTALITY IN LOWER COOK INLET

Age (t)	Number at Age from Original Data (N)	Number at Age from Curve in Figure VI.C.17*	Natural Mortality % from Curve in Figure VI.C.17*	Mortality Coefficient (z)
0	119	128	14	.1510
1	67	110	15	.1570
2	97	94	15	.1610
3	88	80	18	.1920
4	60	66	17	.1820
5	106	55	24	.2697
6	60	42	29	.3365
7	6	30		

*Based on the technique of Gruffydd (1974) in which the number at age from the curve for zero year clams is estimated. All other numbers at age are calculated using the following expression:

$$N_{t+1} = N_t \cdot e^{-z(t)}; \text{ where}$$

N = number of clams
z = mortality coefficient
t = time
t + 1 = time at the next year
e = 2.718



Alaska
Study area
Nuculana fossa
154°
153°
152°
151°
60°
59°
Kalgin Island
Anchor Point
Homer
KACHEMAK BAY
LOWER COOK INLET
KENAI PENINSULA
Augustine Island
KAMISHAK BAY
KENNEDY ENTRANCE
Barren Islands
Cape Douglas
20 km
54
53
49
35
33
28
27
25
18
16
C
8
7
6
5
3
40
39
37

Figure VI.C.8. Distribution of all *Nuculana fossa* collected by van Veen grab and pipe dredge from Cook Inlet Stations.

All Stations (Cook Inlet) *Nuculana fossa*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	Number in Age Class
1	3.7							67
2	3.8	6.7						97
3	3.6	6.1	9.0					88
4	3.5	5.9	8.5	10.9				60
5	3.6	6.4	9.0	11.0	12.9			106
6	3.6	5.8	8.8	11.0	12.5	14.0		60
7	3.5	5.7	8.5	11.4	13.6	15.0	16.2	6
	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION							484

* M S L = Mean Shell Length, mm

Figure VI.C.9. Growth history of *Nuculana fossa* from eight Cook Inlet stations; 5, 6, 27, 28, 33, 37, 49, and 54.

Station 6 (Cook Inlet) *Nuculana fossa*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	Number in Age Class
1								0
2	3.4	6.2						11
3	3.6	6.0	9.0					34
4	3.3	5.6	8.2	10.8				39
5	3.6	6.4	9.0	10.9	12.8			77
6	3.6	5.7	8.7	10.9	12.3	13.8		48
7	3.4	5.6	7.7	10.4	12.3	13.5	14.9	3
	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION							212

*M S L = Mean Shell Length

Figure VI.C.10. Growth history of *Nuculana fossa* from Cook Inlet Station 6.

Station 28 (Cook Inlet) *Nuculana fossa*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	Number in Age Class
1	3.6					32
2	4.0	6.7				11
3	3.4	5.4	7.9			12
4	3.4	5.2	7.3	9.5		3
5	3.4	5.4	7.6	9.9	12.1	2
	1972	1973	1974	1975	1976	Total
	**Y A F					60

*M S L = Mean Shell Length

**Y A F = Year of Annulus Formation

Figure VI.C.11. Growth history of *Nuculana fossa* from Cook Inlet Station 28.

Station 37 (Cook Inlet) *Nuculana fossa*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	Number in Age Class
1	3.6							26
2	3.8	6.7						73
3	3.7	6.3	9.3					34
4	3.8	6.7	9.1	11.4				18
5	3.6	6.5	9.3	11.2	13.4			26
6	3.7	6.5	9.1	11.6	13.2	15.0		12
7	3.3	5.2	9.3	12.8	15.5	17.0	18.3	2
	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION							191

*M S L = Mean Shell Length

Figure VI.C.12. Growth history of *Nuculana fossa* from Cook Inlet Station 37.

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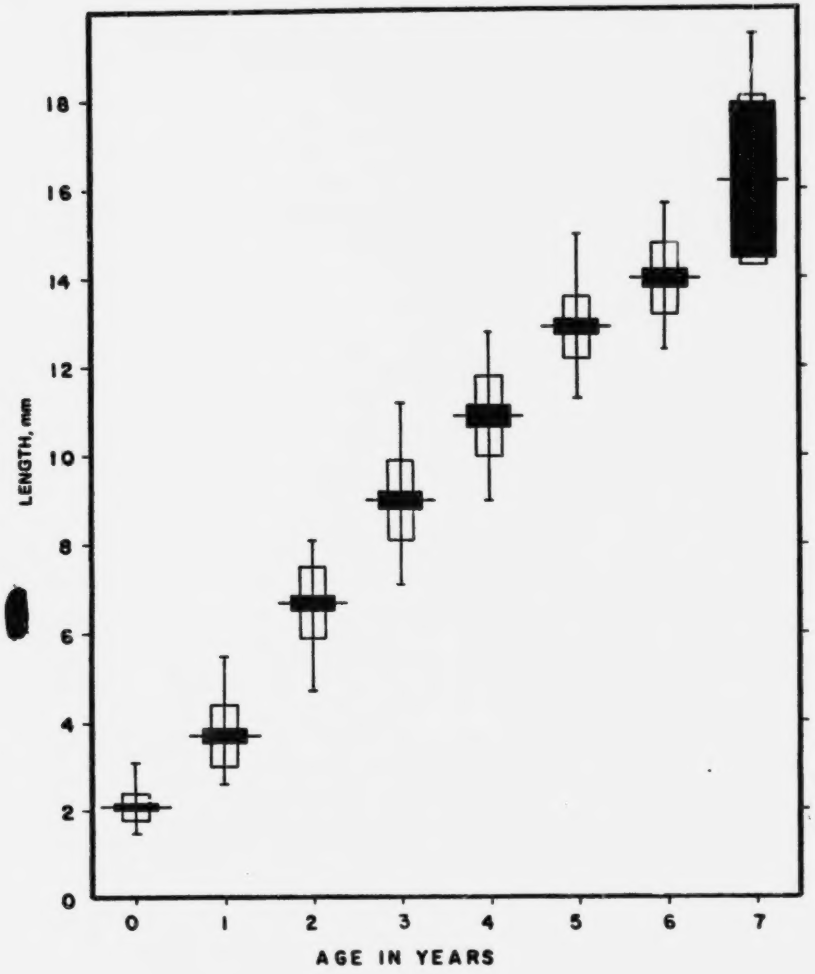

Figure VI.C.13. Growth curve for *Nuculana fossa* from eight Cook Inlet Stations; 5, 6, 27, 28, 33, 37, 49 and 54. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

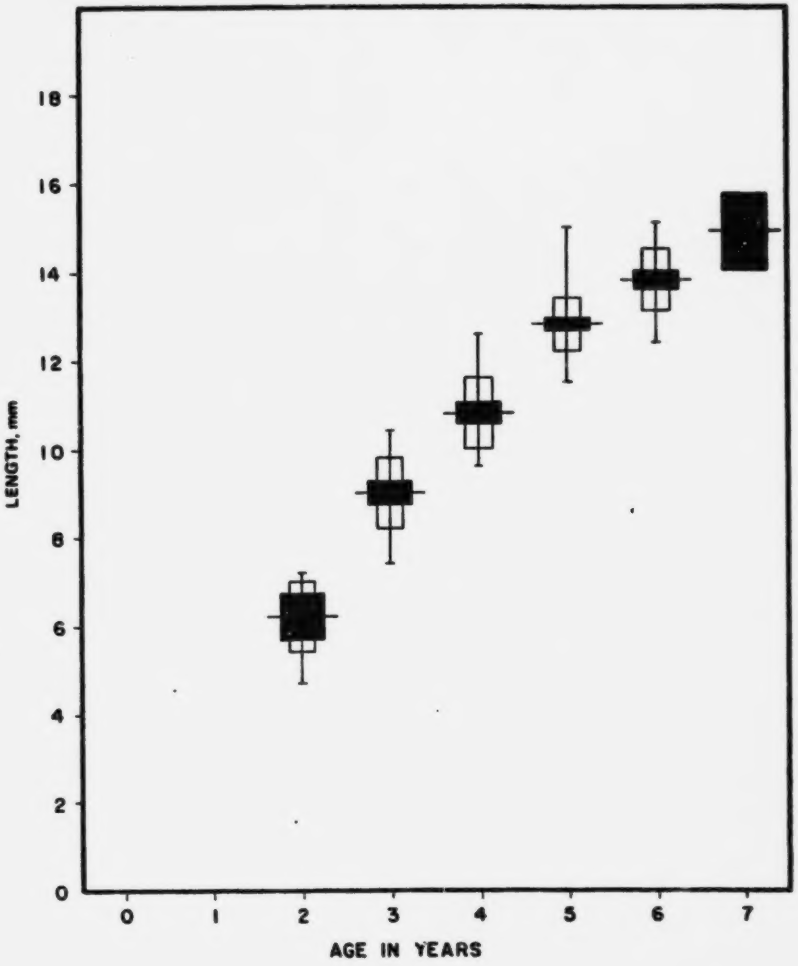

Figure VI.C.14. Growth curve for *Nuculana fossa* from Cook Inlet Station 6. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

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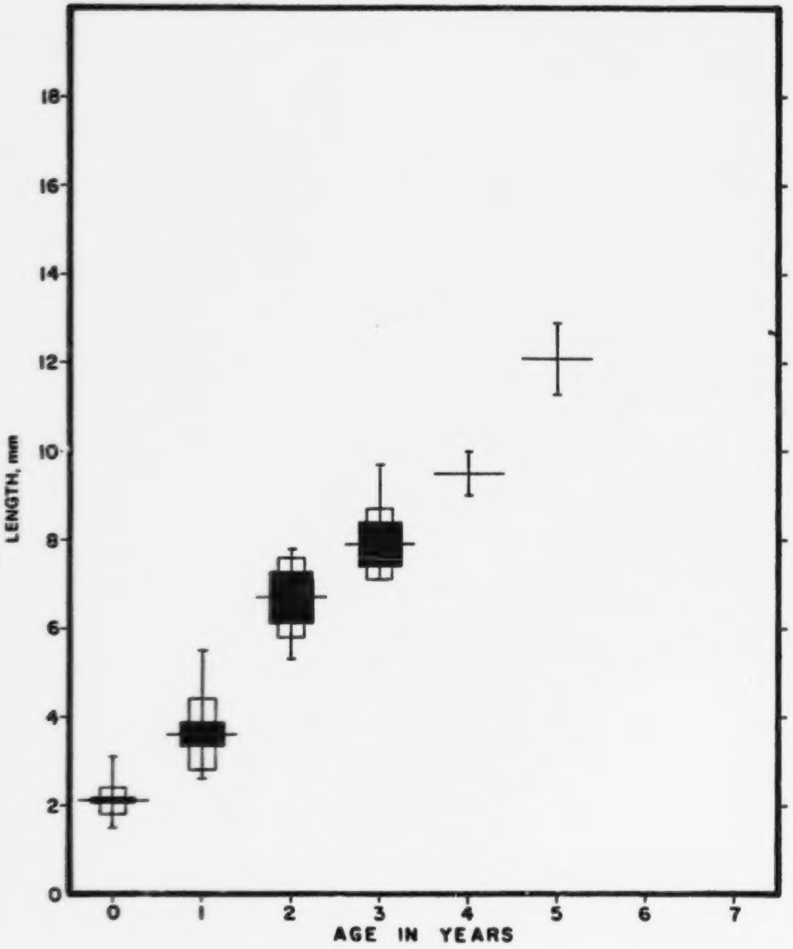

Figure VI.C.15. Growth curve for *Nuculana fossa* from Cook Inlet Station 28. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

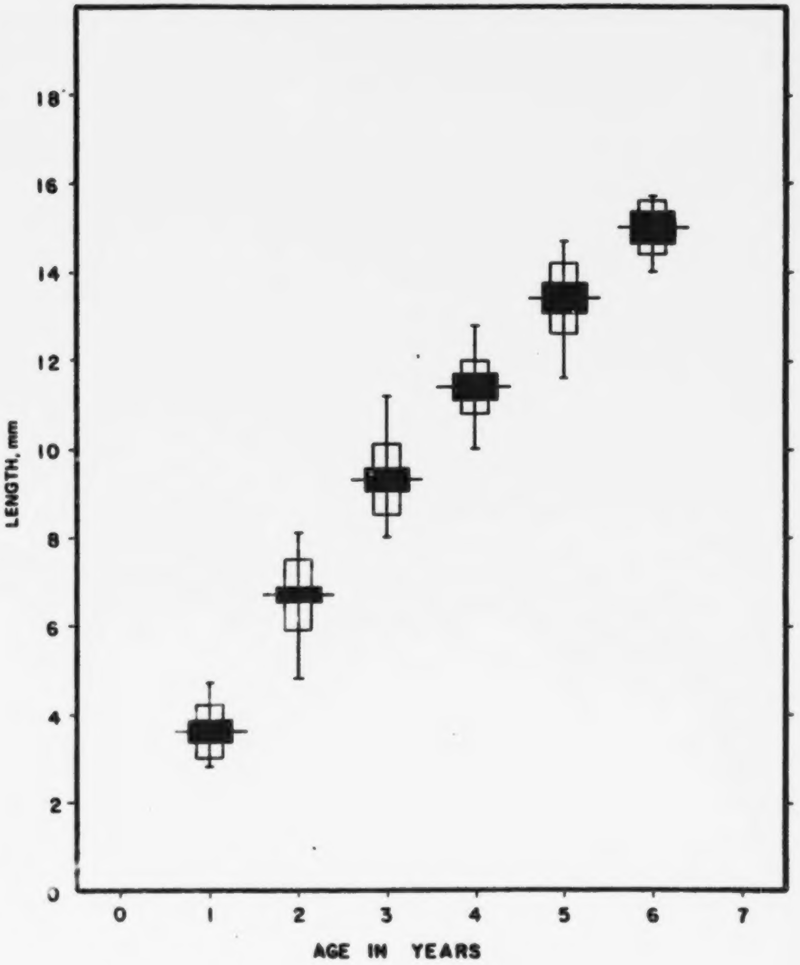

Figure VI.C.16. Growth curve for *Nuculana fossa* from Cook Inlet Station 37. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the veritcal line.

BEST DOCUMENT AVAILABLE

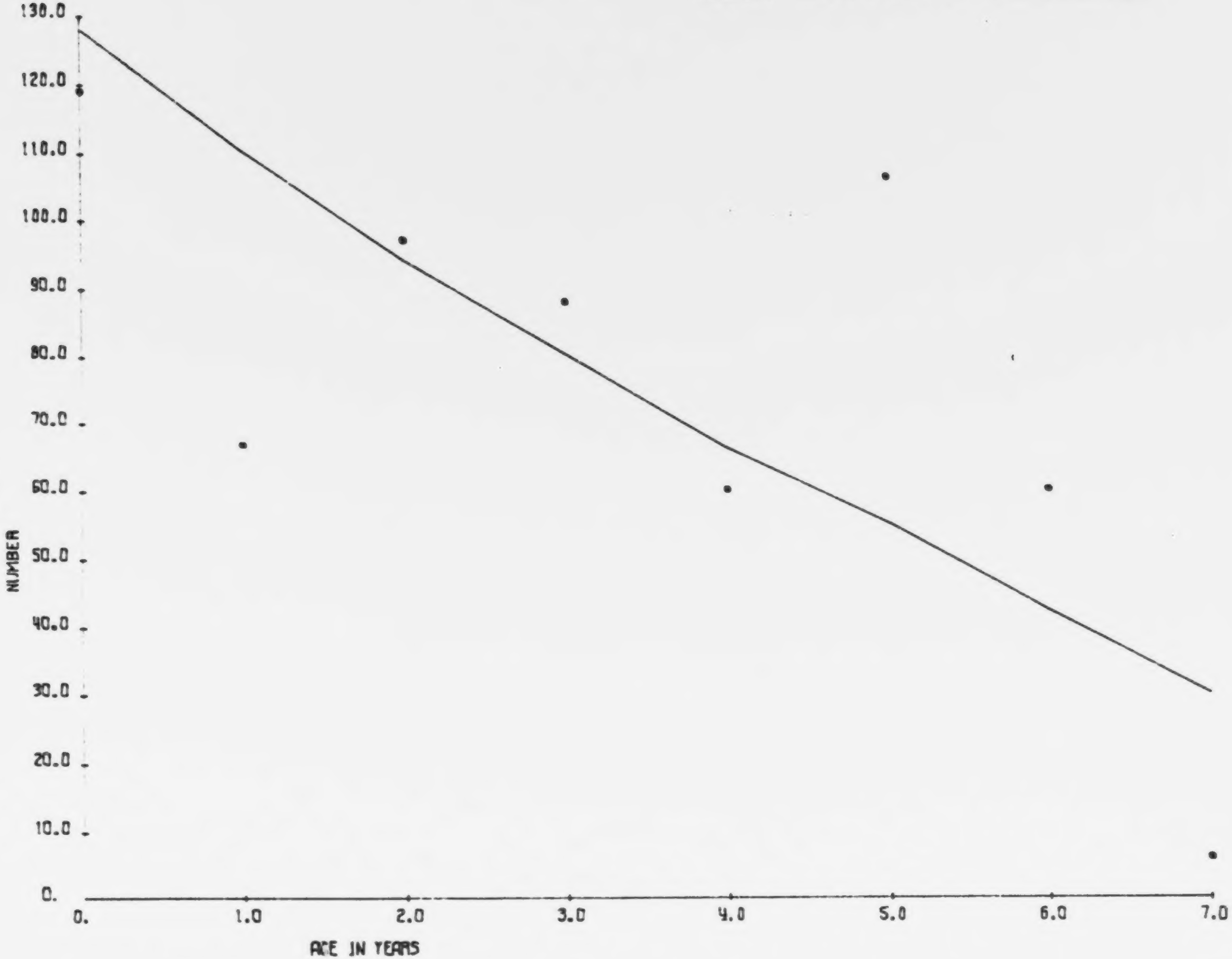

Figure VI.C.17. Graph of abundance vs. age for *Nuculana fossa* in Cook Inlet.

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Glycymeris subobsoleta

Glycymeris subobsoleta was collected at the stations listed in Table VI.C.I and shown in Fig. VI.C.18. There was no apparent gear bias in age sampling of this species, as the age classes were well represented in the collections as shown in age composition Table VI.C.XXI. Eight hundred and seventy-eight *G. subobsoleta* were aged from ten stations; M, UW2, 28, 29, 30, 40A, 42, 44, 45, and 63. The annual increase in shell length for each of the size classes in Cook Inlet was typically 1 to 3 mm (Tables VI.C.XXI-VI.C.XXVII; Figs. VI.C.19-VI.C.28). Growth rates were similar for all stations, and varied only slightly from year to year (Figs. VI.C.19-VI.C.25). The integrity of the age classes is suggested by Figs. VI.C.26 to VI.C.28 where it can be observed that none of the standard errors of the mean overlap. The mean shell length at each annular age showed some variation (Figs. VI.C.19-VI.C.25). However, 235 of the 239 values for mean shell lengths at an annulus (Figs. VI.C.19-VI.C.25) did not exceed the standard deviation around that mean annular length by more than 1 mm (Tables VI.C.XXI-VI.C.XXVII).

The majority of the specimens examined were between 0 and 4 years of age. However, there was considerable variation in the age composition of the collections (Tables VI.C.XXI-VI.C.XXVII). For example, 99% of the *Glycymeris subobsoleta* from Station 28 were between 0 and 1 year of age, while 78% of the clams from Station 42 were 3 to 5 years of age. The oldest and largest *G. subobsoleta* collected were 11 years of age and 27.0 mm in length, respectively.

Dry weights of the various age classes are available in Table VI.C.XXVIII. Biomass estimations (dry tissue weight) for each age class were made for *Glycymeris subobsoleta* at three stations; 28, 42, and 63 (Tables VI.C.XXIX-VI.C.XXXI). Total biomass estimations for these stations ranged from 0.22 to 0.81 g/m^2 (Tables VI.C.XXIX-VI.C.XXXI).

Approximately 20% mortality occurred in the second year class of *Glycymeris subobsoleta*, this gradually increased to 50% by age 10 (Table VI.C.XXXII; Fig. VI.C.29). Calculations using the age composition Tables VI.C.XXI to VI.C.XXVII indicate that extensive mortality occurred after age 4, 92% of the clams were between 0 and 4 years of age. This species is not heavily preyed upon by the large crabs and shrimps of the area as seen in the low frequency of occurrence with which *G. subobsoleta* was found in the stomachs of the common crustacean predators (see Section B). No comparable mortality data are available for the species from other regions of the Gulf of Alaska.

TABLE VI.C.XXI

THE AGE COMPOSITION AND SHELL LENGTHS OF *CLYCYMERIS SUBOBSOLETA* FROM LOWER COOK INLET, THE TEN STATIONS (M, UW2, 28, 29, 30, 40A, 42, 44, 45 and 63) WHERE THE CLAMS WERE COLLECTED (Fig. 16).

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	128	2.1	0.4	0.07	1.3 -2.8
1	475	3.6	0.5	0.04	2.2- 4.9
2	92	5.0	0.7	0.14	4.0- 6.5
3	45	8.3	0.8	0.23	6.3- 9.7
4	65	10.8	0.8	0.20	9.5-12.3
5	26	13.6	0.9	0.37	12.0-15.6
6	16	16.3	1.2	0.64	13.8-18.6
7	8	18.4	1.4	1.09	17.1-21.2
8	14	19.8	1.4	0.80	17.9-22.3
9	6	21.8	1.2	1.11	20.2-23.7
10	2	26.0	0.6	1.24	25.6-26.5
11	1	27.0	0.0	0.00	27.0
	Total = 878				

TABLE VI.C.XXII

THE AGE COMPOSITION AND SHELL LENGTHS OF *GLYCYMERIS SUBOBSOLETA* FROM LOWER COOK INLET STATION 28

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	123	2.1	0.4	0.07	1.3-2.7
1	430	3.6	0.5	0.05	2.2-4.9
2	2	5.1	0.4	0.83	4.8-5.3
	Total = 555				

TABLE VI.C.XXIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *GLYCYMERIS SUBOBSOLETA* FROM LOWER COOK INLET STATION 29

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
3	3	8.5	0.3	0.44	8.1-8.7
4	1	10.9	0.0	0.00	10.9
5	2	13.2	1.7	3.51	12.0-14.4
6	5	16.5	1.1	1.13	15.4-18.3
7	3	19.8	1.2	0.85	18.9-21.2
8	4	19.8	0.8	0.95	19.2-20.9
9	2	22.0	0.6	1.24	21.6-22.4
10	2	26.0	0.6	1.24	25.6-26.5
	Total = 22				

TABLE VI.C.XXIV

THE AGE COMPOSITION AND SHELL LENGTHS OF *GLYCYMERIS SUBOBSOLETA* FROM LOWER COOK INLET STATION 30

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	2	5.3	0.6	1.24	4.8-5.7
3	10	8.7	0.3	0.21	8.2-9.1
4	11	10.6	0.6	0.39	10.0-12.0
5	1	12.2	0.0	0.00	12.2
	Total = 24				

TABLE VI.C.XXV

THE AGE COMPOSITION AND SHELL LENGTHS OF *GLYCYMERIS SUBOBSOLETA* FROM LOWER COOK INLET STATION 40A

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	4	2.6	0.2	0.24	2.4-2.8
1	42	3.6	0.4	0.12	2.9-4.2
2	84	4.9	0.7	0.15	4.0-6.5
3	12	7.6	0.9	0.56	6.3-9.2
4	9	10.5	0.5	0.36	9.6-11.2
5	1	12.2	0.0	0.00	12.2
	Total = 152				

TABLE VI.C.XXVI

THE AGE COMPOSITION AND SHELL LENGTHS OF *GLYCYMERIS SUBOBSOLETA* FROM LOWER COOK INLET STATION 42

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	1	4.1	0.0	0.00	4.1
2	4	5.9	0.4	0.48	5.4-6.3
3	13	8.6	0.8	0.48	7.4-9.7
4	21	10.9	0.9	0.43	9.5-12.3
5	10	13.9	0.9	0.62	12.8-15.6
6	4	16.2	0.6	0.71	15.5-16.7
7	2	17.5	0.6	1.24	17.1-18.0
8	1	22.0	0.0	0.00	22.0

Total = 56

TABLE VI.C.XXVII

THE AGE COMPOSITION AND SHELL LENGTHS OF *GLYCYMERIS SUBOBSOLETA* FROM LOWER COOK INLET STATION 44

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	0	--	--	--	--
3	6	8.2	0.9	0.83	7.1-9.4
4	20	10.9	0.9	0.43	9.6-12.2
5	11	13.5	0.8	0.52	12.6-15.0
6	5	16.8	1.2	1.24	15.6-18.6
7	3	17.5	0.4	0.58	17.1-17.8
8	7	20.0	1.4	1.18	18.0-22.3
9	4	21.7	1.6	1.91	20.2-23.7
10	0	--	--	--	--
11	1	25.0	0.0	0.00	25.0
	Total = 57				

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TABLE VI.C.XXVIII

AGE AND DRY-WEIGHT RELATIONSHIPS OF COOK INLET *GLYCYMERIS SUBOBSOLETA*

Age	Number of Clams	Total Dry Weight (g)*	$\bar{x}$ Total Dry Weight (g)	Total Shell Weight (g)	Total Dry Tissue Weight (g)	$\bar{x}$ Dry Tissue Weight (g)	% Dry Tissue†
0	8	0.039	0.0049	0.036	0.003	0.0004	7.7
1	11	0.184	0.0167	0.173	0.011	0.0010	6.0
2	10	0.459	0.0459	0.434	0.025	0.0025	5.4
3	16	2.510	0.1569	2.337	0.173	0.0108	6.9
4	0	-	-	-	-	-	-
5	10	5.812	0.5812	5.216	0.596	0.0596	10.3
6	6	6.086	1.0143	5.430	0.656	0.1093	10.8
7	6	7.659	1.2765	6.687	0.972	0.1620	12.7
8	10	16.748	1.6748	14.449	2.299	0.2299	13.7
9	11	25.118	2.2835	22.187	2.931	0.2665	11.7
10	1	2.473	2.4730	2.142	0.331	0.3310	13.4

*Total dry weight = total shell weight + total dry tissue weight

†% dry tissue = $\frac{\text{total dry tissue weight}}{\text{total dry weight}} \times 100$

TABLE VI.C.XXIX

GLYCYMERIS SUBOBSOLETA: BIOMASS ESTIMATIONS PER m^2 AT STATION 28

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	87	174	0.0004	0.0696
1	289	578	0.0010	0.5780
Total dry tissue weight in g(biomass)/m^2				0.6476

*See Table VI.C.XXVIII

TABLE VI.C.XXX

GLYCYMERIS SUBOBSOLETA: BIOMASS ESTIMATIONS PER m^2 AT STATION 42

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0004	0
1	0	0	0.0010	0
2	0	0	0.0025	0
3	2	4	0.0108	0.0432
4	1	2	0.0352†	0.0704
5	4	8	0.0596	0.4768
6	1	2	0.1093	0.2186
Total dry tissue weight in g(biomass)/m^2				0.8090

*See Table VI.C.XXVIII

†Number extrapolated

TABLE VI.C.XXXI

GLYCYMERIS SUBOBSOLETA: BIOMASS ESTIMATIONS PER m^2 AT STATION 63

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0004	0
1	0	0	0.0010	0
2	0	0	0.0025	0
3	0	0	0.0108	0
4	0	0	0.0352†	0
5	0	0	0.0596	0
6	1	2	0.1093	0.2186
Total dry tissue weight in g(biomass)/m^2				0.2186

*See Table VI.C.XXVIII

†Number extrapolated

TABLE VI.C.XXXII

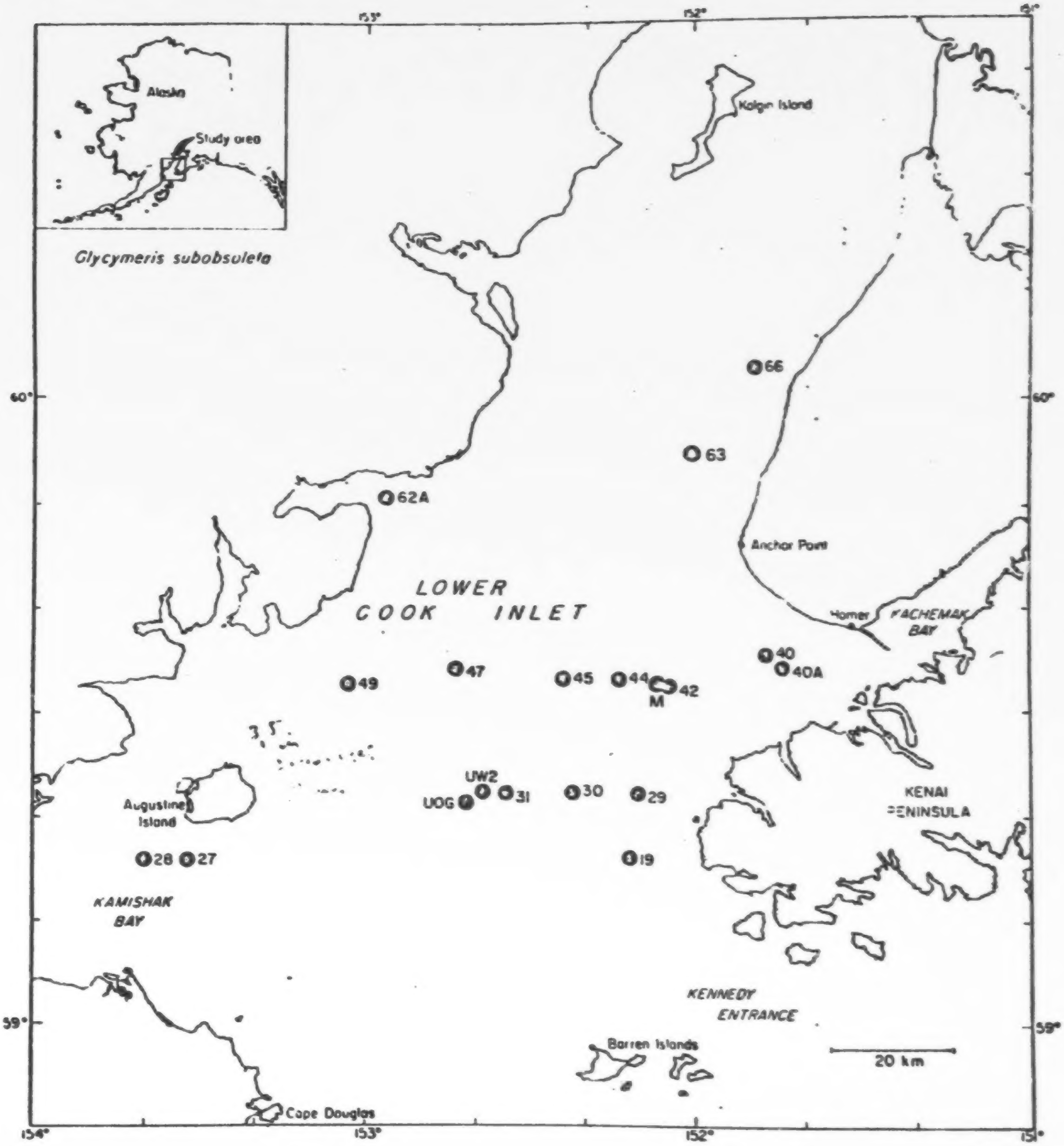
THE NUMBER OF *GLYCYMERIS SUBOBSOLETA* AT EACH AGE, AND THE RELATIONSHIP BETWEEN AGE AND NATURAL MORTALITY IN LOWER COOK INLET

Age (t)	Number at Age from Original Data (N)	Number at Age from Curve in Figure VI.C.29*	Natural Mortality % from Curve in Figure VI.C.29*	Mortality Coefficient (z)
0	128	-	-	-
1	415	-	-	-
2	92	75	20	.2230
3	45	60	23	.2650
4	65	46	24	.2730
5	26	35	29	.3360
6	16	25	36	.4460
7	8	16	44	.5750
8	14	9	67	1.0986
9	6	3	33	.4050
10	2	2	50	.6930
11	1	1		

*Based on the technique of Gruffydd (1974) in which the number at age from the curve for two-year old clams is estimated. All other numbers at age are calculated using the following expression:

$N_{t+1} = N_t \cdot e^{-z(t)}$; where

N = number of clams
z = mortality coefficient
t = time
t + 1 = time at the next year
e = 2.718



Alaska
Study area
Glycymeris subobsoleta
Kalgin Island
Anchor Point
Homer
KACHEMAK BAY
LOWER COOK INLET
KENAI PENINSULA
Augustine Island
KAMISHAK BAY
KENNEDY ENTRANCE
Barren Islands
Cape Douglas
20 km
66
63
62A
40
40A
49
47
45
44
42
M
UW2
UOG
31
30
29
28
27
19
154°
153°
152°
151°
60°
59°

Figure VI.C.18. Distribution map of all *Glycymeris subobsoleta* collected by van Veen grab and pipe dredge from Cook Inlet stations.

All Stations (Cook Inlet) *Glycymeris subobsoleta*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	Number in Age Class
1	3.6											475
2	3.3	5.0										92
3	3.5	5.6	8.3									45
4	3.4	5.5	8.0	10.8								65
5	3.5	5.5	8.1	10.8	13.6							26
6	3.6	5.9	8.4	11.4	13.7	16.3						16
7	3.6	5.7	8.5	11.3	13.9	16.2	18.4					8
8	3.7	5.5	8.0	10.9	13.6	15.9	18.0	19.8				14
9	3.5	5.5	7.8	10.2	12.9	15.7	18.0	20.0	21.8			6
10	3.7	5.8	7.8	11.1	14.4	17.5	20.3	22.3	24.2	26.0		2
11	3.0	5.3	7.2	10.4	13.2	15.6	17.4	21.5	23.4	25.0	27.0	1
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION											750

* M S L = Mean Shell Length, mm

Figure VI.C.19. Growth history of *Glycymeris subobsoleta* from ten Cook Inlet stations; M, UW2, 28, 29, 30, 40A, 42, 44, 45, and 63.

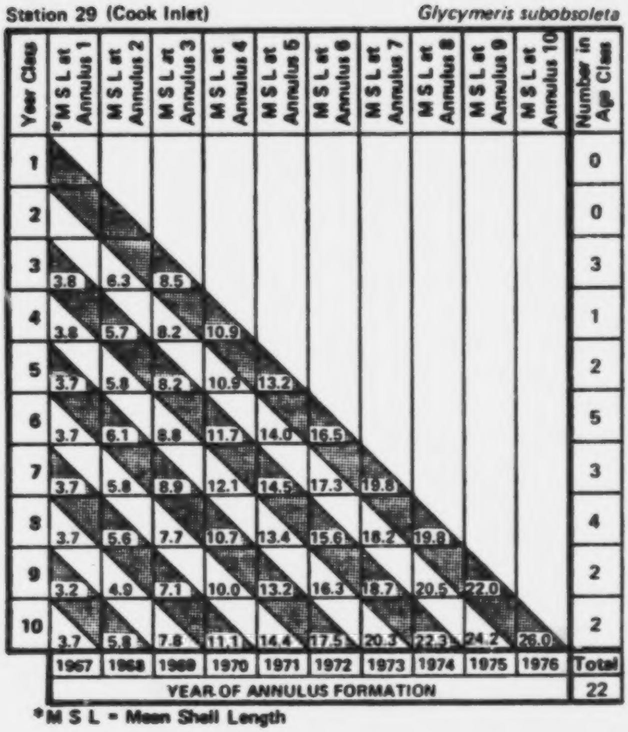
Station 28 (Cook Inlet)
Glycymeris subobsoleta

Year Class	*M S L at Annulus 1	M S L at Annulus 2	Number in Age Class
1	3.6		430
2	3.7	5.1	2
	1975	1976	Total
	**Y A F		432

* M S L = Mean Shell Length

** Y A F = Year of Annulus Formation

Figure VI.C.20. Growth history of *Glycymeris subobsoleta* from Cook Inlet Station 28.

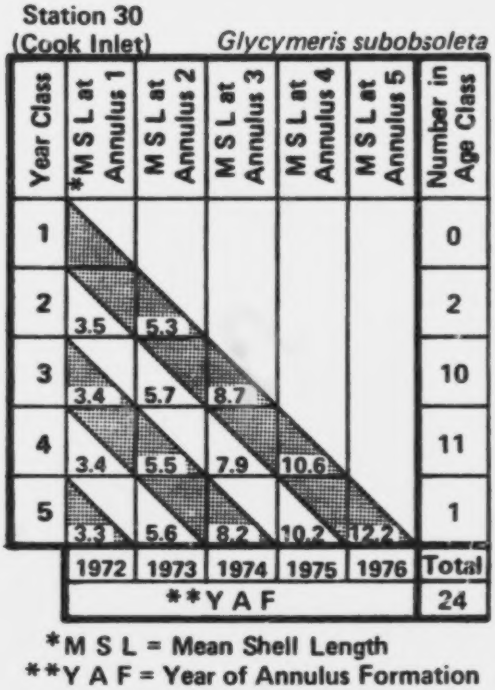


Station 29 (Cook Inlet) *Glycymeris subobsoleta*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	Number in Age Class
1											0
2											0
3	3.8	6.3	8.5								3
4	3.8	5.7	8.2	10.9							1
5	3.7	5.8	8.2	10.9	13.2						2
6	3.7	6.1	8.8	11.7	14.0	16.5					5
7	3.7	5.8	8.9	12.1	14.5	17.3	19.8				3
8	3.7	5.6	7.7	10.7	13.4	15.6	18.2	19.8			4
9	3.2	4.9	7.1	10.0	13.2	16.3	18.7	20.5	22.0		2
10	3.7	5.8	7.8	11.1	14.4	17.5	20.3	22.3	24.2	26.0	2
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION										22

*M S L = Mean Shell Length

Figure VI.C.21. Growth history of *Glycymeris subobsoleta* from Cook Inlet Station 29.



Station 30 (Cook Inlet) *Glycymeris subobsoleta*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	Number in Age Class
1						0
2	3.5	5.3				2
3	3.4	5.7	8.7			10
4	3.4	5.5	7.9	10.6		11
5	3.3	5.6	8.2	10.2	12.2	1
	1972	1973	1974	1975	1976	Total
	**Y A F					24

*M S L = Mean Shell Length
**Y A F = Year of Annulus Formation

Figure VI.C.22. Growth history of *Glycymeris subobsoleta* from Cook Inlet Station 30.

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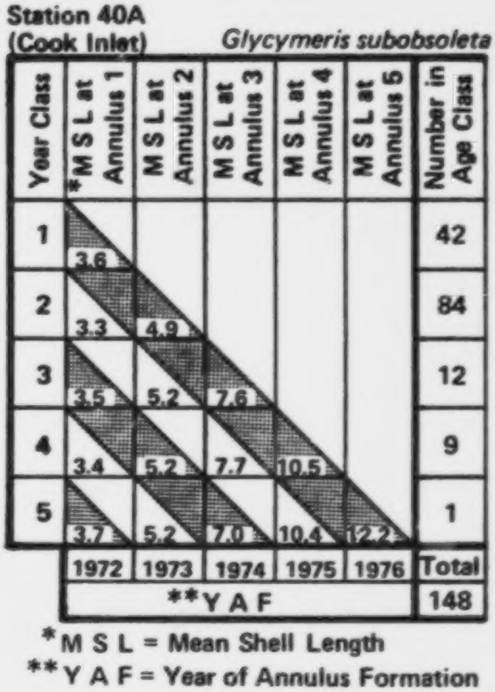


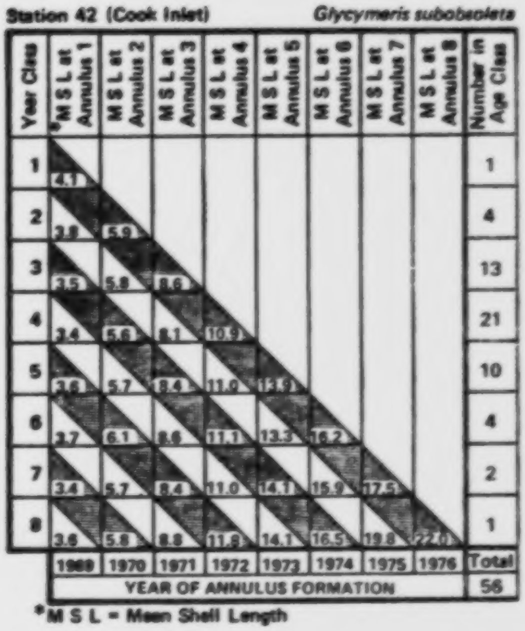
Station 40A (Cook Inlet) *Glycymeris subobsoleta*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	Number in Age Class
1	3.6					42
2	3.3	4.9				84
3	3.5	5.2	7.6			12
4	3.4	5.2	7.7	10.5		9
5	3.7	5.2	7.0	10.4	12.2	1
	1972	1973	1974	1975	1976	Total
	**Y A F					148

*M S L = Mean Shell Length

**Y A F = Year of Annulus Formation

Figure VI.C.23. Growth history of *Glycymeris subobsoleta* from Cook Inlet Station 40A.

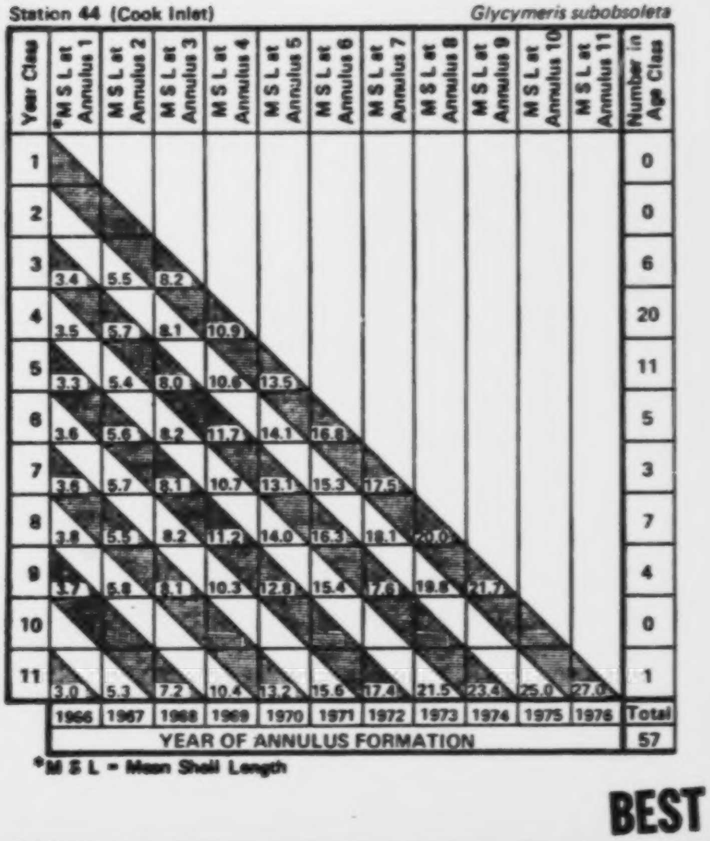


Station 42 (Cook Inlet) *Glycymeris subobsoleta*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	Number in Age Class
1	4.1								1
2	3.8	5.9							4
3	3.5	5.8	8.6						13
4	3.4	5.6	8.1	10.9					21
5	3.6	5.7	8.4	11.0	13.9				10
6	3.7	6.1	8.6	11.1	13.3	16.2			4
7	3.4	5.7	8.4	11.0	14.1	15.9	17.5		2
8	3.6	5.8	8.8	11.8	14.1	16.5	19.8	22.0	1
	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION								56

*M S L = Mean Shell Length

Figure VI.C.24. Growth history of *Glycymeris subobsoleta* from Cook Inlet Station 42.



Station 44 (Cook Inlet) *Glycymeris subobsoleta*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	Number in Age Class
1												0
2												0
3	3.4	5.5	8.2									6
4	3.5	5.7	8.1	10.9								20
5	3.3	5.4	8.0	10.6	13.5							11
6	3.6	5.6	8.2	11.7	14.1	16.8						5
7	3.6	5.7	8.1	10.7	13.1	15.3	17.5					3
8	3.8	5.5	8.2	11.2	14.0	16.3	18.1	20.0				7
9	3.7	5.8	8.1	10.3	12.8	15.4	17.6	19.8	21.7			4
10												0
11	3.0	5.3	7.2	10.4	13.2	15.6	17.4	21.5	23.4	25.0	27.0	1
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION											57

*M S L = Mean Shell Length

Figure VI.C.25. Growth history of *Glycymeris subobsoleta* from Cook Inlet Station 44.

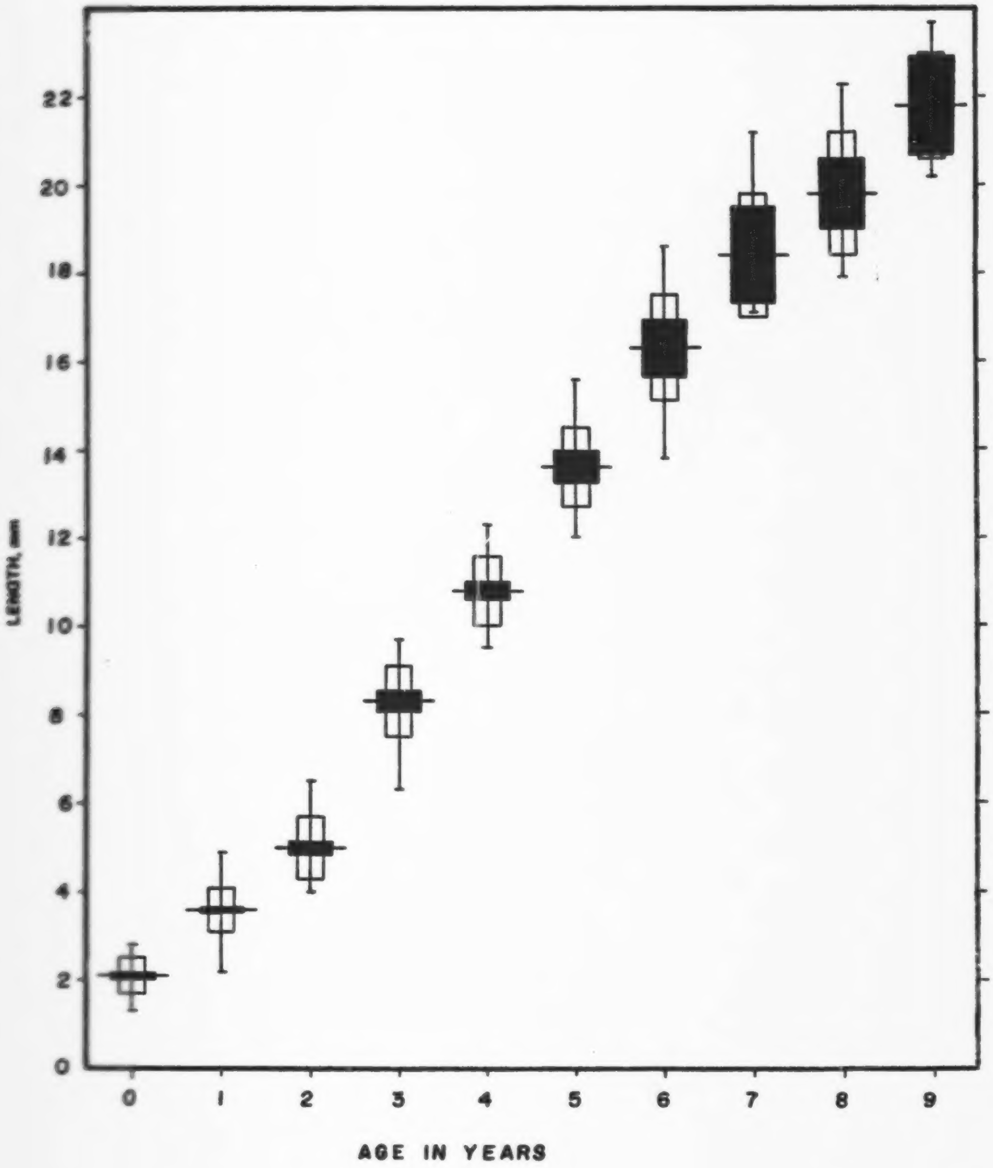


Figure VI.C.26. Growth curve for *Glycymeris subobsoleta* from ten Cook Inlet stations; M, UW2, 28, 29, 30, 40A, 42, 44, 45, and 63. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

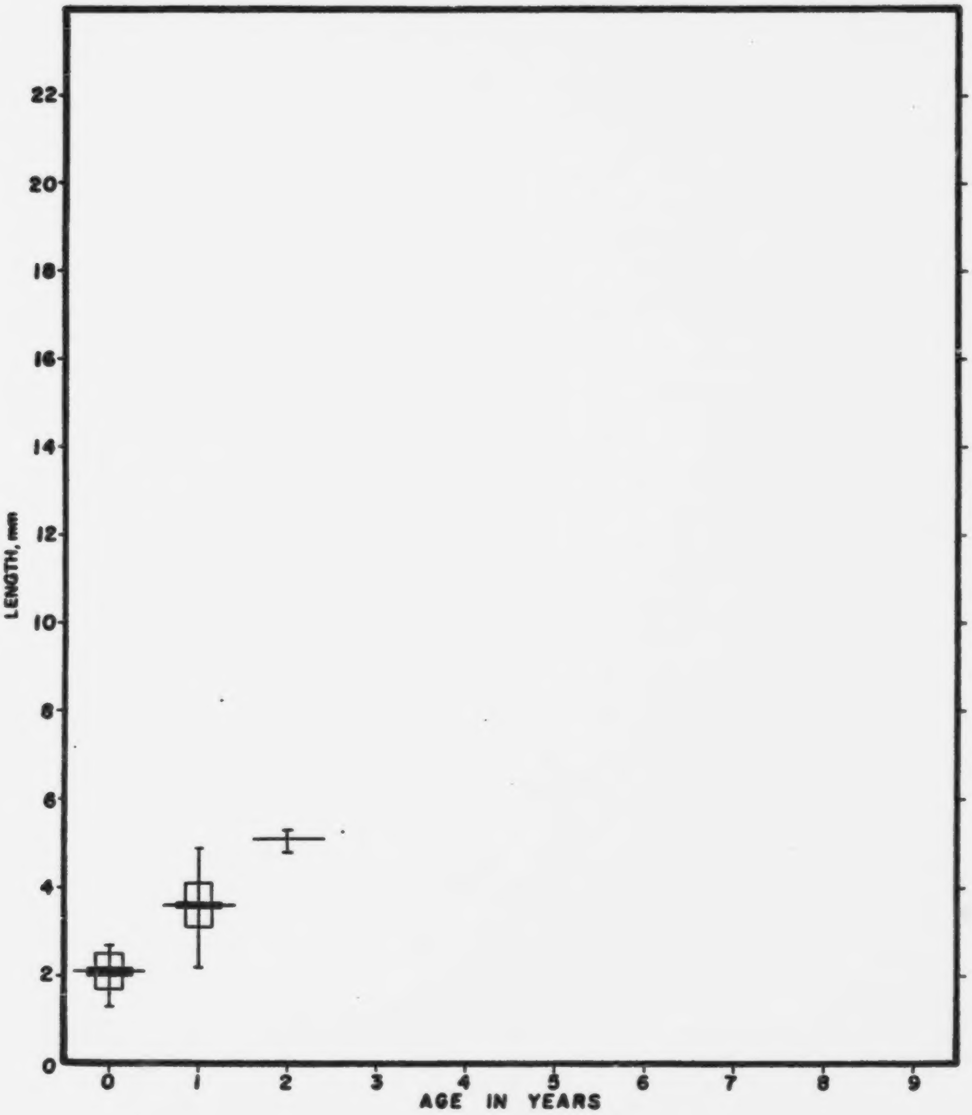


Figure VI.C.27. Growth curve for *Glycymeris subobsoleta* from Cook Inlet Station 28. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

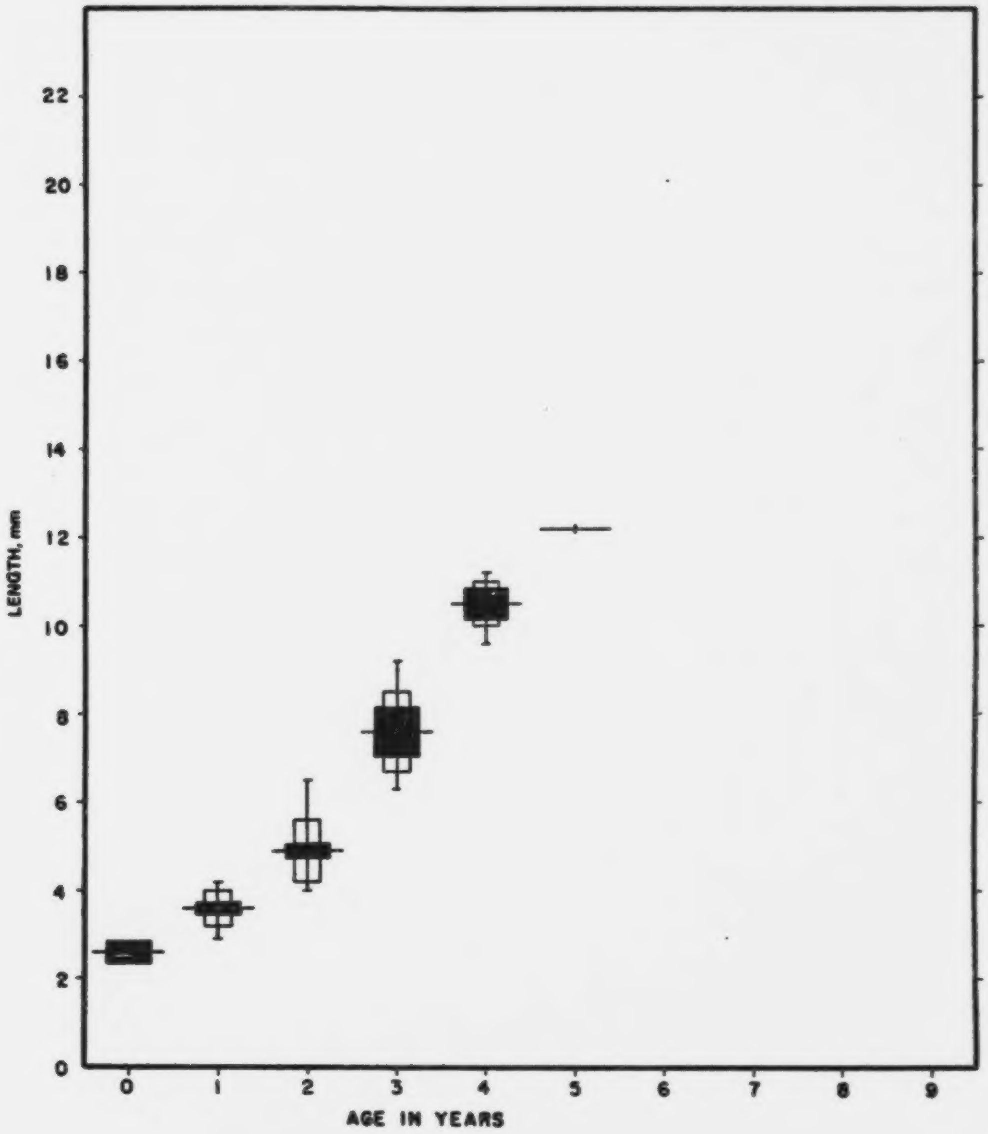


Figure VI.C.28. Growth curve for *Glycymeris subobsoleta* from Cook Inlet Station 40A. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

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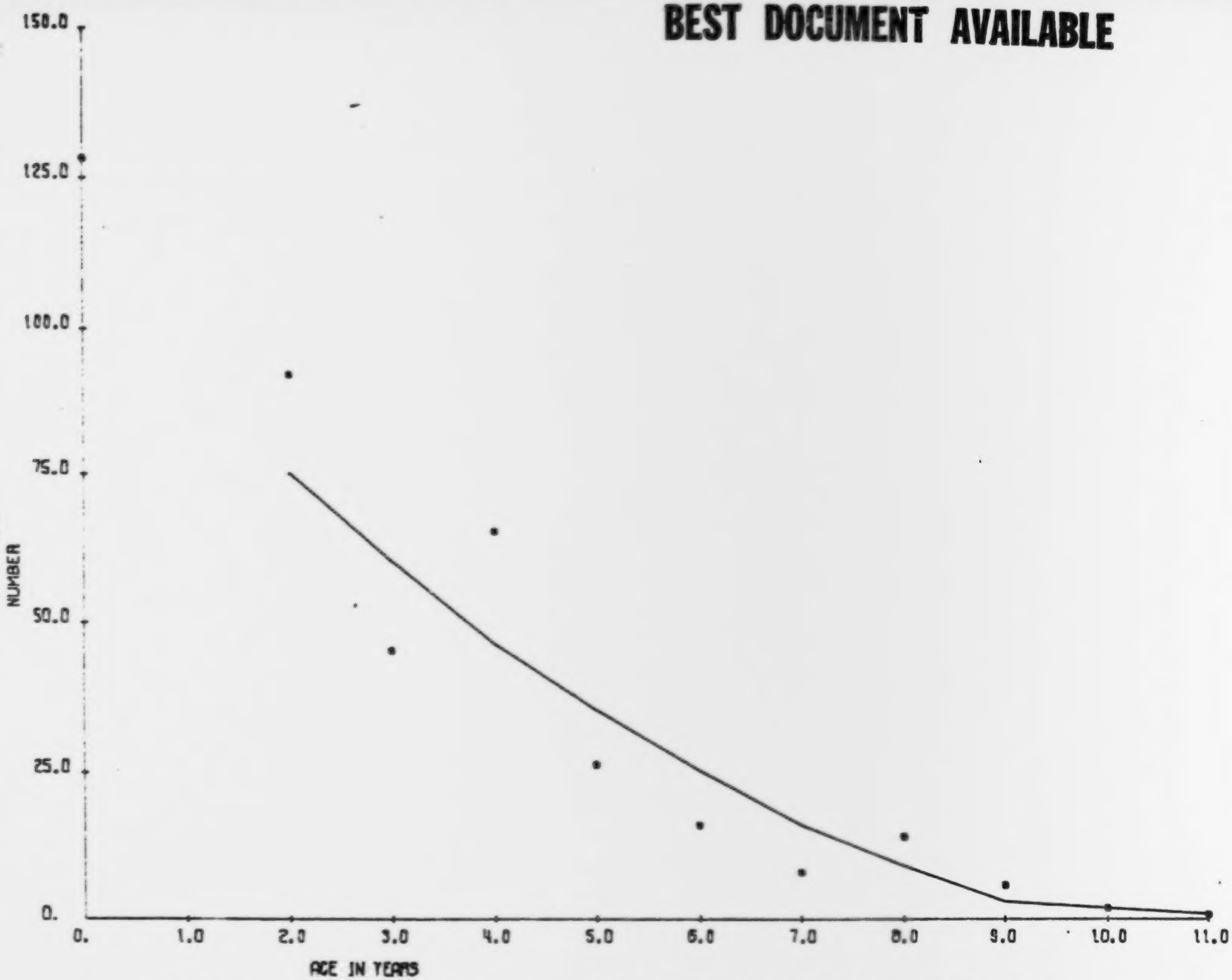

Figure VI.C.29. Graph of abundance vs. age for *Glycymeris subobsoleta* in Cook Inlet.

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Spisula polynyma

Spisula polynyma was collected at the stations listed in Table VI.C.I and shown in Fig. VI.C.30 (excluding DG stations). Of the specimens over 30 mm in length, five were fresh-frozen specimens provided by the Alaska Department of Fish and Game and 74 were empty shells collected by anchor dredge. The sampling gear used in the present survey did not adequately sample all size classes of *S. polynyma*. Therefore, observations on the biology of this clam were restricted to age and growth. Five hundred and fifty-six *S. polynyma* were aged from seven stations; 40A, 41, 42, DG 1, DG 2, DG 3, and DG 4. The annual increase in shell length for various size classes in Cook Inlet was typically 5 to 9 mm (Tables VI.C.XXXIII-VI.C.XXXVI; Figs. VI.C.31-VI.C.38). Growth was similar at all stations, and varied only slightly from year to year for age groups 0 to 4 (Figs. VI.C.31-VI.C.34). The integrity of the age classes is suggested by Figs. VI.C.35 to VI.C.38 where it can be observed that none of the standard errors of the mean overlap. The growth histories for the mean shell lengths at annuli 1 through 3 (Figs. VI.C.31-VI.C.34) were similar, only 11 out of 126 mean annular lengths exceeded the standard deviations included in Tables VI.C.XXXIII to VI.C.XXXVI by more than 1 mm. However, 68% of the mean shell lengths for annulus 4 (Figs. VI.C.31-VI.C.34) exceeded the standard deviations by more than 1 mm. No live *S. polynyma* older than 4 years of age occurred in the samples.

The majority of the 556 specimens examined were between 1 and 4 years of age. Beyond 4 years of age, sample sizes were small and comparisons could not be made. The oldest clams were 16 years of age at a variety of sizes; the largest clam examined was 128 mm in length and 13 years of age. A similar maximum size, 127 mm at 16 years of age, is reported for *S. polynyma* in the southeastern Bering Sea (Feder *et al.*, 1978). This clam grows somewhat larger, 152 mm at 16 years of age, in Prince William Sound, Alaska (Feder *et al.*, 1976).

Dry weights of the various age classes collected by the van Veen grab are available in Table VI.C.XXXVII.

Similar growth, size at age (Tables VI.C.XXXIII-VI.C.XXXVI; Figs. VI.C.35-VI.C.38) and growth histories (Figs. VI.C.31-VI.C.34) were observed for *Spisula polynyma* from each of the Cook Inlet stations examined. Data appearing in Table VI.C.LXIV compares size at age from three studies: Feder *et al.* (1976), Feder *et al.* (1978), and this report. Feder *et al.* (1976) reported mean shell lengths of 8, 13, 22, 32, 43, 57, 66, 77, 88, 98, 108, 115, 122, 127, 133, and 139 mm in length for *S. polynyma* from Prince William Sound for age classes 1 to 16, respectively. Feder *et al.* (1978) reported mean shell lengths of 12, 28, 35, 48, 57, 69, 78, 85, 94, 101, 108, 114, 121, 123, and 127 mm from the eastern Bering Sea for age classes 2 to 16. These shell lengths compare with 10, 15, 21, 26, 38, 43, no data, 82, 80, 92, 98, 107, 112, 114, 120, and 118 mm in mean shell lengths for our Cook Inlet specimens for age classes 1 to 16; therefore, this clam appears to grow sightly faster in Prince William Sound (Table VI.C.LXIV).

TABLE VI.C.XXXIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *SPISULA POLYNYMA* FROM LOWER COOK INLET FROM SEVEN STATIONS (40A, 41, 42, DG 1, DG 2, DG 3, and DG 4)* (See Table VI.C.I and Fig. VI.C.27)

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	5	0	0	5
1	128	10	1.2	0.2	5-12
2	117	15	2.2	0.4	11-20
3	175	21	2.1	0.3	16-27
4	56	26	2.3	0.6	20-30
5	1**	38	0	0	38
6	1**	43	0	0	43
7	0	--	--	--	--
8	1**	82	0	0	82
9	3**	80	5.9	7.0	73-84
10	5**	92	6.6	6.1	82-99
11	16**	98	5.1	2.6	90-107
12	16**	107	5.3	2.7	96-113
13	14**	112	7.3	4.0	100-128
14	14*	114	4.0	2.2	107-120
15	4*	120	6.2	6.4	112-127
16	4*	118	4.0	2.0	114-123
Total = 556					

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* DG station locations can be obtained from ADF&G, Homer, Alaska.
**Empty shells.

TABLE VI.C.XXXIV

THE AGE COMPOSITION AND SHELL LENGTHS OF *SPISULA POLYNYMA* FROM LOWER COOK INLET STATION 41

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	4	9	1.8	1.9	7-11
2	21	15	2.5	1.1	11-19
3	108	22	1.8	0.3	18-27
4	56	26	2.3	0.6	20-30
5	1*	38	0	0	38
6	1*	43	0	0	43
7	0	--	--	--	--
8	1*	82	0	0	82
9	3*	80	5.9	7.0	73-84
10	5*	92	6.6	6.1	82-99
11	14*	97	4.3	2.4	90-106
12	8*	106	5.3	3.9	96-113
13	2*	103	3.5	7.3	100-105
14	3*	112	3.0	3.6	109-115
	Total = 227				

*Empty shells.

TABLE VI.C.XXXV

THE AGE COMPOSITION AND SHELL LENGTHS OF *SPISULA POLYNYMA* FROM LOWER COOK INLET STATION DG 1

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	6	10	0.5	0.4	10-11
2	70	16	1.6	0.4	12-20
3	56	19	1.7	0.4	16-24
4	0	--	--	--	--
5	0	--	--	--	--
6	0	--	--	--	--
7	0	--	--	--	--
8	0	--	--	--	--
9	0	--	--	--	--
10	0	--	--	--	--
11	0	--	--	--	--
12	0	--	--	--	--
13	1	122	0	0	122
14	2	117	4.2	8.8	114-120
Total = 135					

TABLE VI.C.XXXVI

THE AGE COMPOSITION AND SHELL LENGTHS OF *SPISULA POLYNYMA* FROM LOWER COOK INLET STATION DG 2

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	5	0	0	5
1	85	10	1.1	0.2	5-12
2	22	14	2.6	1.1	12-19
3	9	19	1.3	0.9	17-21
4	0	--	--	--	--
5	0	--	--	--	--
6	0	--	--	--	--
7	0	--	--	--	--
8	0	--	--	--	--
9	0	--	--	--	--
10	0	--	--	--	--
11	0	--	--	--	--
12	0	--	--	--	--
13	1	113	0	0	113
14	0	--	--	--	--
15	0	--	--	--	--
16	1	123	0	0	123
	Total = 119				

TABLE VI.C.XXXVII

AGE AND DRY-WEIGHT RELATIONSHIPS OF COOK INLET *SPISULA POLYNYMA*

Age	Number of Clams	Total Dry Weight (g)*	$\bar{x}$ Total Dry Weight (g)	Total Shell Weight (g)	Total Dry Tissue Weight (g)	$\bar{x}$ Dry Tissue Weight (g)	% Dry Tissue†
0	30	0.147	0.0049	0.121	0.026	0.00087	17.7
1	20	0.471	0.0236	0.389	0.082	0.00410	17.4
2	5	0.850	0.1700	0.678	0.172	0.03440	20.2

[*] Total dry weight = total shell weight + total dry tissue weight

[†] % dry tissue = $\frac{\text{total dry tissue weight}}{\text{total dry weight}} \times 100$

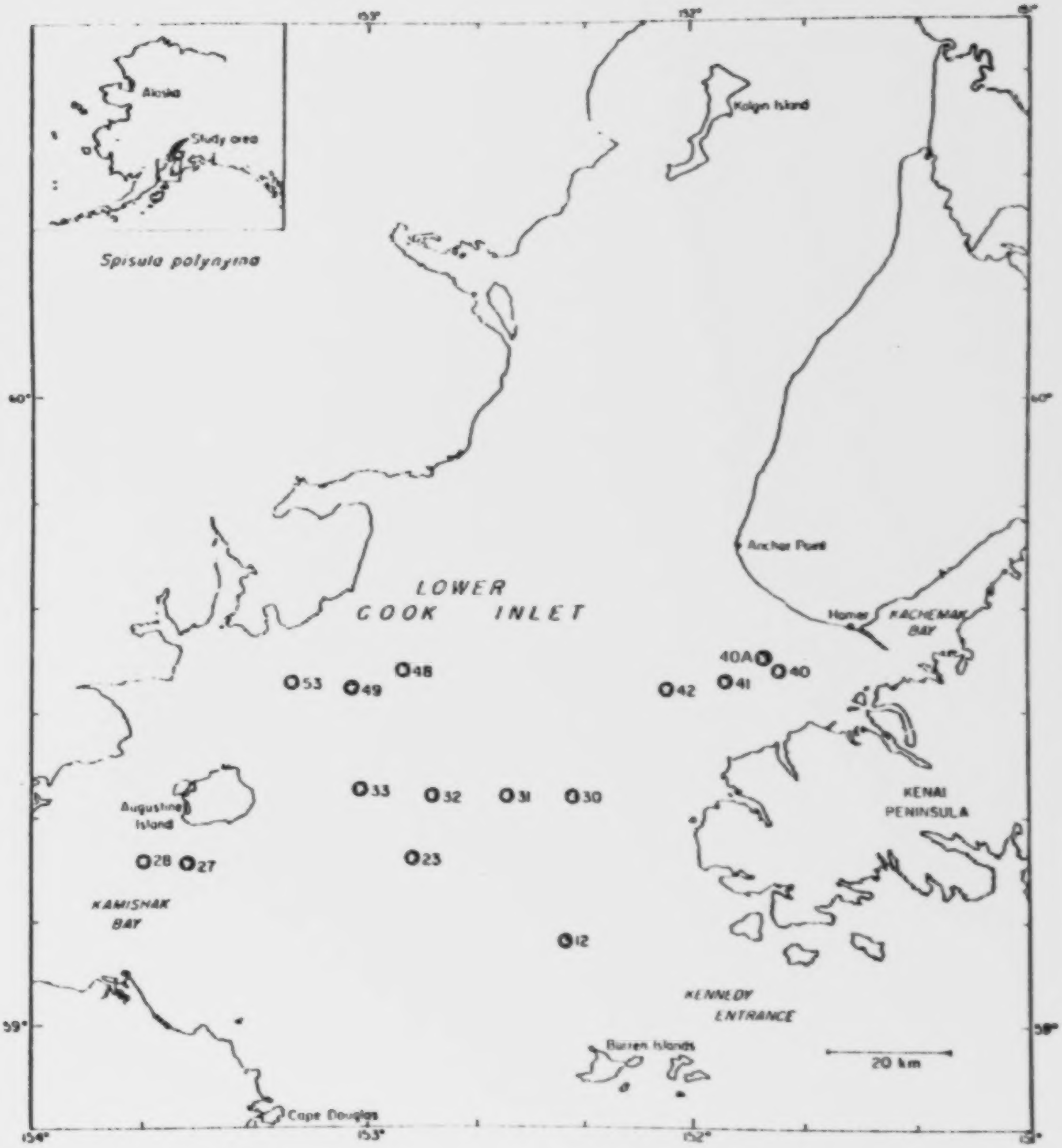
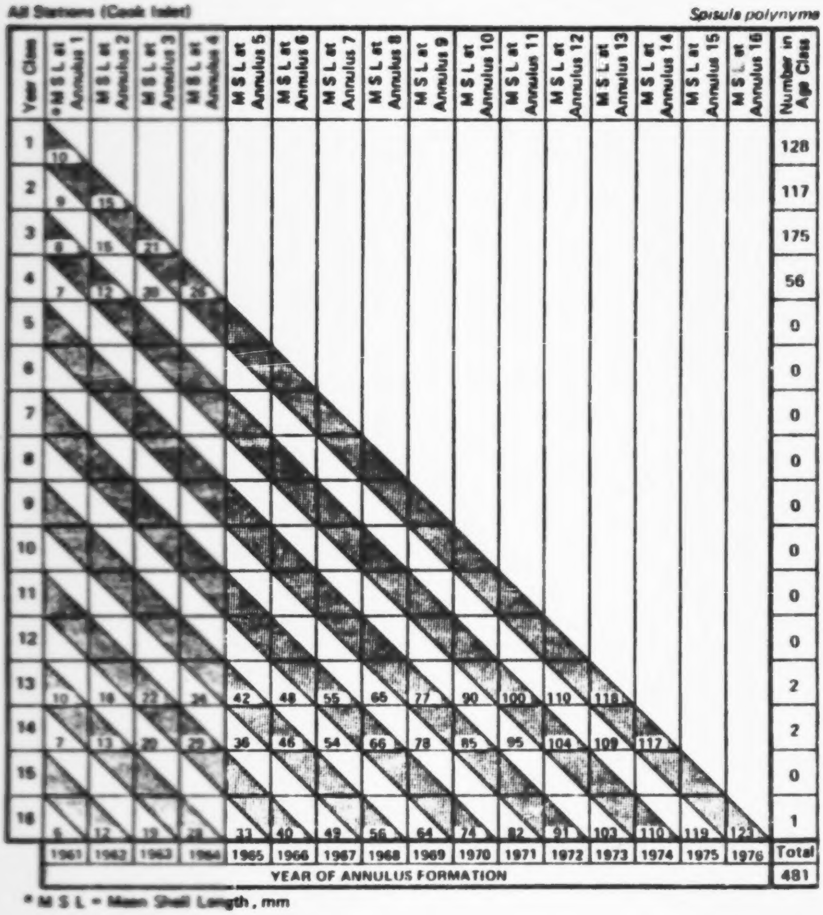

153°
152°
151°
60°
59°
154°
Alaska
Study area
Spisula polynyma
Kalgin Island
Anchor Point
Homer
KACHEMAK BAY
LOWER COOK INLET
40A
40
41
42
48
53
49
33
32
31
30
23
12
28
27
Augustine Island
KAMISHAK BAY
KENAI PENINSULA
KENNEDY ENTRANCE
Barren Islands
20 km
Cape Douglas

Figure VI.C.30. Distribution map of all *Spisula polynyma* collected by van Veen grab and pipe dredge from Cook Inlet stations.

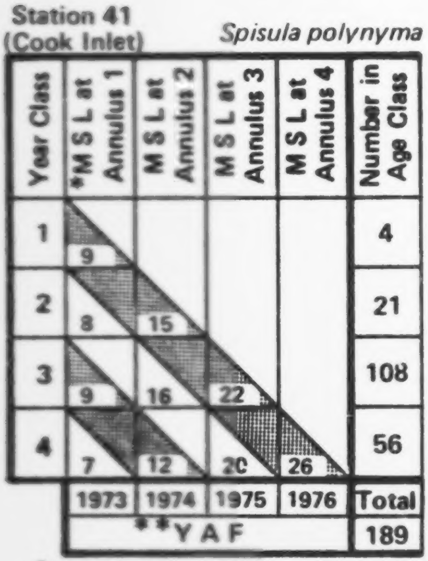


All Stations (Cook Inlet) *Spisula polynyma*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	M S L at Annulus 15	M S L at Annulus 16	Number in Age Class
1	10																128
2	9	15															117
3	8	15	21														175
4	7	12	20	26													56
5																	0
6																	0
7																	0
8																	0
9																	0
10																	0
11																	0
12																	0
13	10	16	22	34	42	48	55	65	77	90	100	110	118				2
14	7	13	20	29	36	46	54	66	78	85	95	104	109	117			2
15																	0
16	6	12	19	28	33	40	49	56	64	74	82	91	103	110	119	123	1
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION																481

* M S L = Mean Shell Length, mm

Figure VI.C.31. Growth history of *Spisula polynyma* from seven Cook Inlet stations; 40A, 41, 42, DG1, DG2, DG3, and DG4.



Station 41 (Cook Inlet) *Spisula polynyma*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	Number in Age Class
1	9				4
2	8	15			21
3	9	16	22		108
4	7	12	20	26	56
	1973	1974	1975	1976	Total
	**Y A F				189

*M S L = Mean Shell Length
**Y A F = Year of Annulus Formation

Figure VI.C.32. Growth history of *Spisula polynyma* from Cook Inlet Station 41.

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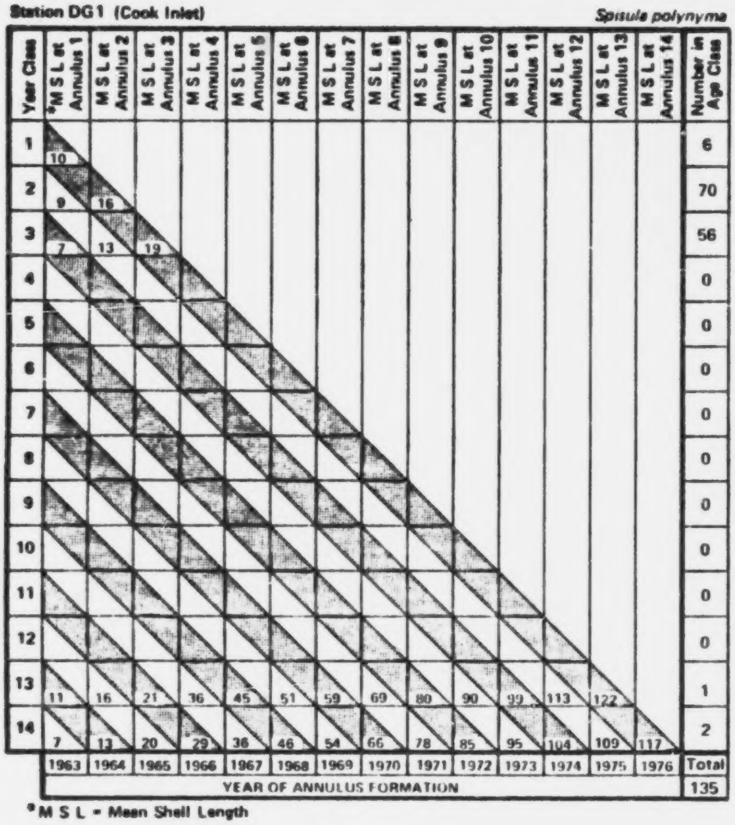
BEST DOCUMENT AVAILABLE

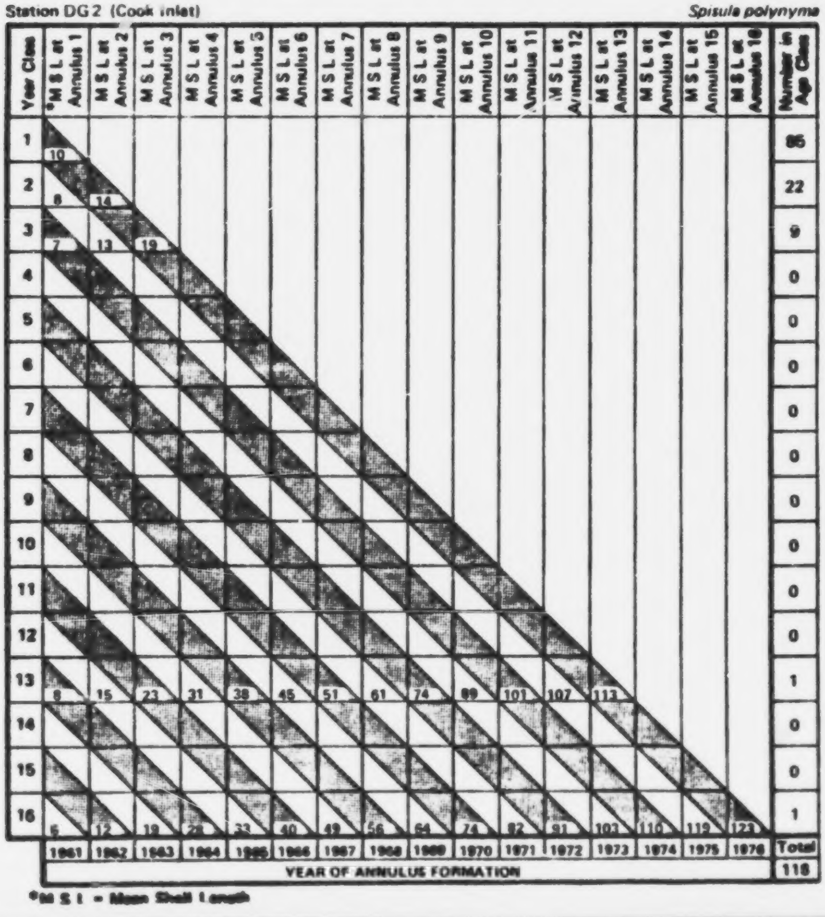


Station DG1 (Cook Inlet) *Spisula polynyma*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	Number in Age Class
1	10														6
2	9	16													70
3	7	13	19												56
4															0
5															0
6															0
7															0
8															0
9															0
10															0
11															0
12															0
13	11	16	21	36	45	51	59	69	80	90	99	113	122		1
14	7	13	20	29	36	46	54	66	78	85	95	104	109	117	2
	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION														135

*M S L = Mean Shell Length

Figure VI.C.33. Growth history of *Spisula polynyma* from Cook Inlet station DG1.



Station DG2 (Cook Inlet) *Spisula polynyma*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	M S L at Annulus 15	M S L at Annulus 16	Number in Age Class
1	10																85
2	8	14															22
3	7	13	19														9
4																	0
5																	0
6																	0
7																	0
8																	0
9																	0
10																	0
11																	0
12																	0
13	8	15	23	31	38	45	51	61	74	89	101	107	113				1
14																	0
15																	0
16	5	12	19	28	33	40	49	56	64	74	82	91	103	110	119	123	1
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION																118

*M S L = Mean Shell Length

Figure VI.C.34. Growth history of *Spisula polynyma* from Cook Inlet Station DG2.

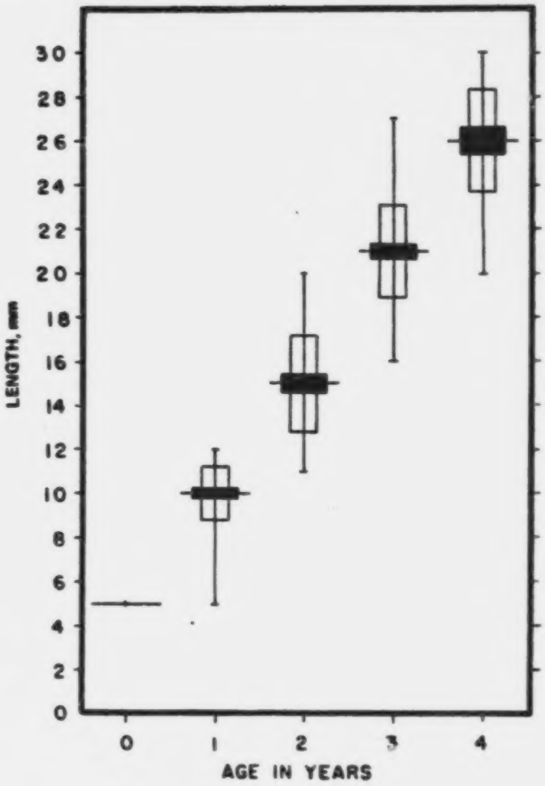


Figure VI.C.35. Growth curve for *Spisula polynyma* from seven Cook Inlet Stations; 40A, 41, 42, DG1, DG2, DG3, and DG4. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

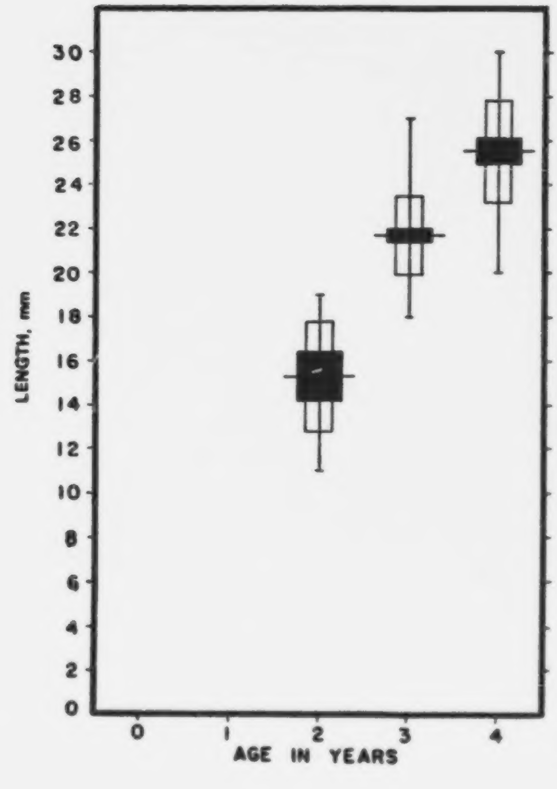


Figure VI.C.36. Growth curve for *Spisula polynyma* from Cook Inlet Station 41. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

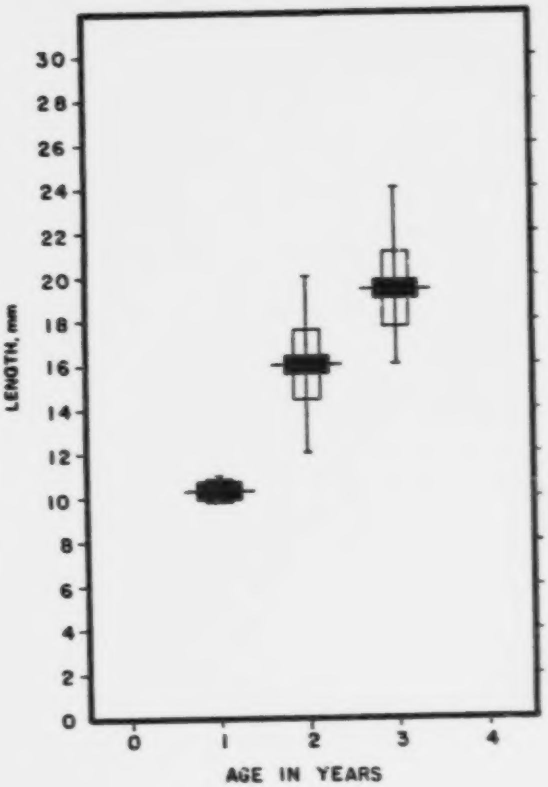


Figure VI.C.37. Growth curve for *Spisula polynyma* from Cook Inlet Station DG1. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

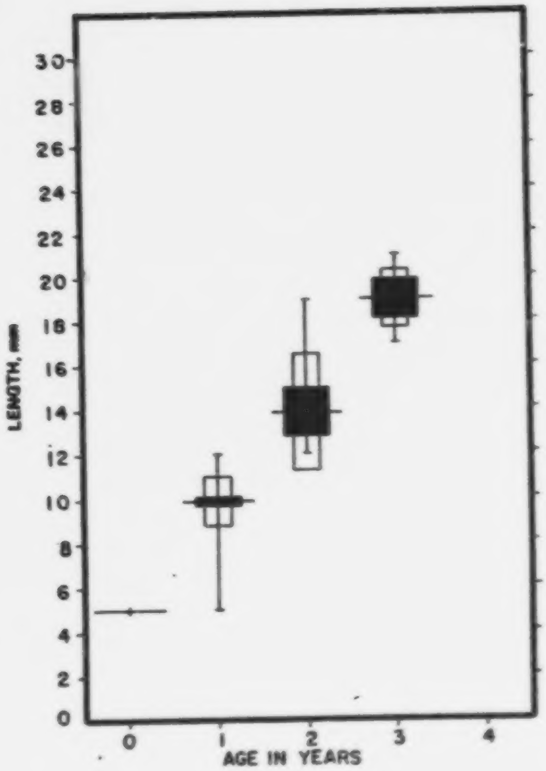


Figure VI.C.38. Growth curve for *Spisula polynyma* from Cook Inlet Station DG2. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

Macoma calcarea

Macoma calcarea was collected at the stations listed in Table VI.C.I and shown in Fig. VI.C.39. There was no apparent gear bias in age sampling of *M. calcarea*, as all age classes were well represented in the collection as shown in age composition Table VI.C.XXXVIII. Five hundred and twenty *M. calcarea* were aged from thirteen stations; C, 18, 25, 27, 28, 32, 33, 35, 37, 39, 49, 53, and 54. The annual increases in shell length for each of the size classes in Cook Inlet was typically 1.3 to 2.7 mm (Tables VI.C.XXXVIII-VI.C.XLVI; Figs. VI.C.40-VI.C.49). Growth was similar at all stations, and varied only slightly from year to year (Figs. VI.C.40-VI.C.45). The integrity of the age classes is suggested in Figs. VI.C.46 to VI.C.49 where it can be observed that none of the standard errors of the mean overlap. The mean shell lengths at each annular age showed some variation (Figs. VI.C.40-VI.C.45). However, 294 of the 300 values for mean shell lengths at an annulus (Figs. VI.C.40-VI.C.45) did not exceed the standard deviation around that mean annular length by more than 1 mm (Tables VI.C.XXXVIII-VI.C.XLVI).

The majority of the 520 specimens examined were between 0 and 5 years of age. However, there was considerable variation in the age composition of the collections (Tables VI.C.XXXVIII-VI.C.XLVI). For example, 90% of the *Macoma calcarea* from Station 28 were in the 0 age class, while 79% of the clams from Station 53 were between 3 and 5 years of age. The oldest and largest *M. calcarea* collected was 14 years of age and 31.4 mm in length, respectively. This species attains 48.8 mm in length at age 9 as indicated by data from the Bering Sea (Feder *et al.*, 1980).

Dry weights of the various age classes are available in Table VI.C.XLVII. Biomass estimations (dry tissue weight) for each age class were made for *Macoma calcarea* at Stations 27, 28, 32, and 33. Total *M. calcarea* biomass for these stations ranged from 0.05 to 1.00 g/m^2 (Tables VI.C.XLVIII-VI.C.LI).

Approximately 38% mortality occurred in the third year class of *Macoma calcarea*, this gradually increased to 50% by age 9 (Table VI.C.LII; Fig. VI.C.50). Calculations using the age composition Tables VI.C.XXXVIII to VI.C.XLVI indicate that extensive mortality occurred after 5 years of age, 94% of the clams were between 0 and 5 years of age. Mortality estimations include ages 3 through 10. These calculations indicate that natural mortality rates are on the order of 40% by age 4 (Table VI.C.LII; Fig. VI.C.50). This species can live for up to 14 years (Table VI.C.XXXVIII). That predation may be an important factor controlling the mortality rates of *M. Calcarea* is suggested by (1) the high mortality rates that occur early in the life span, and (2) the relatively high numbers of young individuals collected in the samples. Paul *et al.* (1979a) reports this species is heavily preyed upon by snow crabs of the area (see Section B). No comparable mortality data are available for this species from other regions of the Gulf of Alaska. *Macoma calcarea* exhibits similar mortality rates in the eastern Bering Sea. There, 50% mortality rates are reached by age 4 and few individuals live longer than 6 years of age (Feder *et al.*, 1980).

Similar growth, size at age (Tables VI.C.XXXVIII-VI.C.XLVI; Figs. VI.C.46-VI.C.49), and growth histories (Figs. VI.C.40-VI.C.45) were observed for *Macoma calcarea* from the Cook Inlet stations examined. Data appearing in Table VI.C.LXIV compares size at age from three studies: Neiman (1964), Feder *et al.*, (1980), and this report. Neiman (1964) reported mean shell lengths of 2.0, 4.1, 6.4, 10.7, 16.9, and 17.9 mm for *M. calcarea* from the eastern Bering Sea for age classes 0 through 5, respectively. Feder *et al.* (1980) reported mean shell lengths of 2.1, 4.3, 6.4, 8.2, 10.2, and 12.9 mm, for *M. calcarea* from the eastern Bering Sea for age classes 0 through 5. These shell lengths compare with 1.9, 3.4, 5.3, 7.4, 9.2, and 11.9 mm for our Cook Inlet specimens; therefore, this clam appears to grow slightly faster in the eastern Bering Sea. (Table VI.C.LXIV).

TABLE VI.C.XXXVIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET FROM THIRTEEN STATIONS (C, 18, 25, 27, 28, 32, 33, 35, 37, 39, 49, 53, and 54) (See Table VI.C.I and Fig. VI.C.36)

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	318	1.9	0.3	0.03	1.0-2.6
1	29	3.4	0.7	0.28	2.6-4.8
2	15	5.3	0.5	0.25	4.6-6.1
3	49	7.4	0.7	0.19	6.1-8.7
4	49	9.2	0.9	0.26	7.5-11.2
5	27	11.9	4.7	1.89	9.9-16.2
6	9	14.3	0.8	0.59	13.0-15.4
7	3	16.9	1.3	1.85	15.5-17.9
8	2	18.2	1.7	3.50	17.0-19.4
9	4	20.1	0.8	0.94	19.4-21.2
10	4	22.4	0.4	0.46	22.0-22.8
11	4	24.2	1.2	1.47	23.3-26.0
12	3	26.7	1.3	1.85	25.7-28.1
13	3	28.3	0.8	1.13	27.7-29.2
14	1	31.4	0.0	0.00	31.4
	Total = 520				

TABLE VI.C.XXXIX

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET STATION 18

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	3	4.2	0.7	0.95	3.5-4.8
2	1	6.0	0.0	0.00	6.0
3	8	7.9	0.5	0.38	7.3-8.7
4	5	9.7	0.9	0.91	8.9-11.2
5	3	12.3	1.3	1.92	11.6-13.1
6	2	14.8	0.1	0.29	14.7-14.9

Total = 22

TABLE VI.C.XL

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET STATION 27

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	4	4.3	0.3	0.39	3.9-4.7
2	4	5.0	0.3	0.34	4.8-5.4
3	10	7.1	0.7	0.47	6.0-8.6
4	18	8.6	0.7	0.34	7.5-10.2
5	3	11.3	1.6	2.37	10.7-12.5
6	0	--	--	--	--
7	0	--	--	--	--
8	0	--	--	--	--
9	1	19.4	0.0	0.00	19.4
10	1	22.8	0.0	0.00	22.8
11	1	23.5	0.0	0.00	23.5

Total = 42

TABLE VI.C.XLI

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET STATION 28

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	317	1.9	0.3	0.03	1.0-2.6
1	15	2.9	0.3	0.16	2.6-3.6
2	2	5.4	0.4	0.73	5.1-5.6
3	7	7.2	0.8	0.70	6.1-8.3
4	7	9.6	0.7	0.62	8.5-10.4
5	3	12.6	5.7	8.36	9.9-16.2
6	0	--	--	--	--
7	1	15.5	0.0	0.00	15.5

Total = 352

TABLE VI.C.XLII

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET STATION 33

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	3	3.2	0.5	0.77	2.8-3.8
2	2	5.6	0.4	0.73	5.4-5.9
3	10	7.2	0.6	0.39	6.2-7.9
4	8	9.0	0.8	0.63	8.0-10.1
5	5	12.1	1.2	1.20	11.2-13.1
6	0	--	--	--	--
7	0	--	--	--	--
8	1	19.4	0.0	0.00	19.4

Total = 29

TABLE VI.C.XLIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET STATION 35

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	1	5.5	0.0	0.00	5.5
3	0	--	--	--	--
4	5	10.3	0.4	0.46	9.9-10.9
5	2	12.3	0.5	1.03	12.0-12.5
6	2	13.1	0.1	0.15	13.0-13.1
	Total = 10				

TABLE VI.C.XLIV

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET STATION 39

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	1.5	0.0	0.00	1.5
1	4	3.9	0.7	0.88	3.1-4.8
2	1	5.5	0.0	0.00	5.5
3	4	7.5	0.6	0.74	6.6-8.0
4	1	10.7	0.0	0.00	10.7
5	5	11.9	2.1	2.15	10.3-13.5
6	2	14.8	0.9	1.90	14.1-15.4
7	2	17.7	0.4	0.73	17.4-17.9
8	0	--	--	--	--
9	1	21.2	0.0	0.00	21.2
10	1	22.2	0.0	0.00	22.2
11	1	26.0	0.0	0.00	26.0
12	1	28.1	0.0	0.00	28.1
13	0	--	--	--	--
14	1	31.4	0.0	0.00	31.4
	Total = 25				

TABLE VI.C.XLV

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET STATION 49

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	0	--	--	--	--
3	2	7.1	0.6	1.31	6.6-7.5
4	2	10.0	1.2	2.48	9.1-10.8
5	0	--	--	--	--
6	1	14.7	0.0	0.00	14.7
7	0	--	--	--	--
8	1	17.0	0.0	0.00	17.0
9	1	19.7	0.0	0.00	19.7
10	1	22.0	0.0	0.00	22.0
11	1	23.3	0.0	0.00	23.3
12	2	26.0	0.4	0.73	25.7-26.2
Total =	11				

TABLE VI.C.XLVI

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM LOWER COOK INLET STATION 54

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	3	4.9	0.3	0.45	4.6-5.2
3	4	7.3	0.6	0.69	6.8-8.1
4	2	9.3	0.1	0.29	9.2-9.4
5	4	11.7	1.4	1.72	10.7-12.7
6	2	14.5	0.4	0.73	14.2-14.7
Total =	15				

TABLE VI.C.XLVII

AGE AND DRY-WEIGHT RELATIONSHIPS OF COOK INLET *MACOMA CALCAREA*

Age	Number of Clams	Total Dry Weight (g)[*]	$\bar{x}$ Total Dry Weight (g)	Total Shell Weight (g)	Total Dry Tissue Weight (g)	$\bar{x}$ Dry Tissue Weight (g)	% Dry Tissue[†]
0	5	0.014	0.0028	0.008	0.006	0.0012	42.9
1	18	0.072	0.0040	0.048	0.024	0.0013	33.3
2	25	0.209	0.0084	0.155	0.054	0.0022	25.8
3	21	0.402	0.0191	0.292	0.110	0.0052	27.4
4	10	0.398	0.0398	0.300	0.098	0.0098	24.6
5	5	0.311	0.0622	0.245	0.066	0.0132	21.2
6	3	0.384	0.1280	0.282	0.102	0.0340	26.6
7	2	0.377	0.1885	0.299	0.078	0.0390	20.7
8	5	1.191	0.2382	0.970	0.221	0.0442	18.6
9	2	0.677	0.3385	0.537	0.140	0.0700	20.7
10	4	2.053	0.5133	1.575	0.478	0.1195	23.3
11	6	3.446	0.5743	2.724	0.722	0.1203	21.0
12	2	1.719	0.8595	1.334	0.385	0.1925	22.4
13	2	2.575	1.2875	1.943	0.632	0.3160	24.5

[*] Total dry weight = total shell weight + total dry tissue weight

[†] % dry tissue = $\frac{\text{total dry tissue weight}}{\text{total dry weight}} \times 100$

TABLE VI.C.XLVIII

MACOMA CALCAREA: BIOMASS ESTIMATIONS PER m^2 AT STATION 27

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0012	0
1	1	2	0.0013	0.0026
2	0	0	0.0022	0
3	1	2	0.0052	0.0104
4	3	6	0.0098	0.0588
Total dry tissue weight in g(biomass)/m^2				0.0718

*See Table VI.C.XLVII

TABLE VI.C.XLIX

MACOMA CALCAREA: BIOMASS ESTIMATIONS PER m^2 AT STATION 28

Age	Number in 6 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	317	528	0.0012	0.6336
1	15	25	0.0013	0.0325
2	2	3	0.0022	0.0066
3	7	12	0.0052	0.0624
4	7	12	0.0098	0.1176
5	3	5	0.0132	0.0660
6	0	0	0.0340	0
7	1	2	0.0390	0.0780
Total dry tissue weight in g(biomass)/m^2				0.9967

*See Table VI.C.XLVII

TABLE VI.C.L

MACOMA CALCAREA: BIOMASS ESTIMATIONS PER m^2 AT STATION 32

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0012	0
1	0	0	0.0013	0
2	0	0	0.0022	0
3	0	0	0.0052	0
4	0	0	0.0098	0
5	2	4	0.0132	0.0528
Total dry tissue weight in g(biomass)/m^2				0.0528

*See Table XLVII

TABLE VI.C.LI

MACOMA CALCAREA: BIOMASS ESTIMATIONS PER m^2 AT STATION 33

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0012	0
1	0	0	0.0013	0
2	0	0	0.0022	0
3	2	4	0.0052	0.0208
4	2	4	0.0098	0.0392
5	1	2	0.0132	0.0264
Total dry tissue weight in g(biomass)/m^2				0.0864

*See Table XLVII

TABLE VI.C.LII

THE NUMBER OF *MACOMA CALCAREA* AT EACH AGE, AND THE RELATIONSHIP BETWEEN AGE AND NATURAL MORTALITY IN LOWER COOK INLET

Age (t)	Number at Age from Original Data (N)	Number at Age from Curve in Figure VI.C.50*	Natural Mortality % from Curve in Figure VI.C.50*	Mortality Coefficient (z)
0	318	-	-	-
1	29	-	-	-
2	15	-	-	-
3	49	60	38	.4834
4	49	37	46	.6152
5	27	20	40	.5100
6	9	12	42	.5389
7	3	7	57	.8473
8	2	3	33	.4000
9	4	2	50	
10	4	2		
11	4	1		
12	3	1		
13	3	1		
14	1	1		

*Based on the technique of Gruffydd (1974) in which the number at age from the curve for three-year old clams is estimated. All other numbers at age are calculated using the following expression:

$N_{t+1} = N_t \cdot e^{-z(t)}$; where

N = number of clams
z = mortality coefficient
t = time
t + 1 = time at the next year
e = 2.718

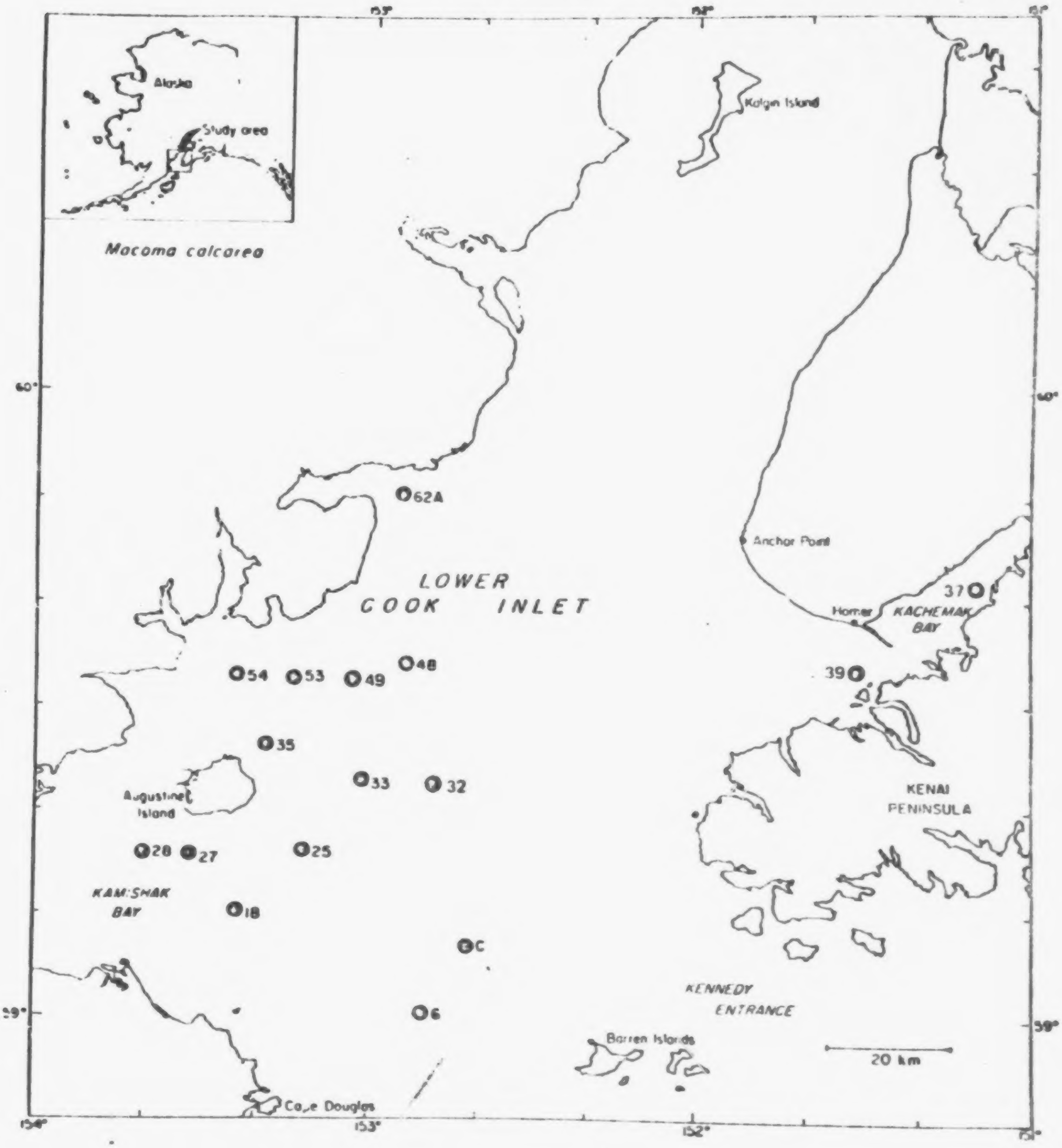

Alaska
Study area
Macoma calcarea
Kalgin Island
Anchor Point
Homer
KACHEMAK BAY
LOWER COOK INLET
KENAI PENINSULA
Augustine Island
KAMISHAK BAY
KENNEDY ENTRANCE
Barren Islands
Cape Douglas
20 km
62A
54
53
49
48
35
33
32
28
27
25
18
C
6
37
39
60°
59°
154°
153°
152°
151°

Figure VI.C.39. Distribution map of all *Macoma calcarea* collected by van Veen grab and pipe dredge from lower Cook Inlet stations.

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All Stations (Cook Inlet) *Macoma calcarea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	Number in Age Class
1	3.4														29
2	3.7	5.3													15
3	3.7	5.6	7.4												49
4	3.6	5.6	7.4	9.2											49
5	3.7	5.8	8.0	10.1	11.9										27
6	3.9	6.0	7.9	10.6	12.4	14.3									9
7	3.9	6.0	8.4	10.7	12.4	14.9	16.9								3
8	3.9	5.5	7.9	9.8	11.9	13.9	16.1	18.2							2
9	3.9	5.8	8.0	9.9	12.2	14.1	16.1	18.3	20.1						4
10	3.7	5.6	8.0	9.9	12.6	13.9	16.3	19.0	20.7	22.4					4
11	3.7	6.0	8.6	10.8	12.7	14.6	16.6	18.5	20.2	22.3	24.2				4
12	4.3	6.1	8.3	10.1	12.5	15.2	17.4	19.5	21.1	22.7	24.6	26.7			3
13	3.4	5.7	8.2	10.9	12.1	14.0	17.0	19.3	21.1	22.8	24.6	26.3	28.3		3
14	3.8	5.7	7.5	9.7	12.8	14.4	15.5	18.3	21.4	23.4	25.0	27.1	29.3	31.4	1
	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION														202

* M S L = Mean Shell Length, mm

Figure VI.C.40. Growth history of *Macoma calcarea* from thirteen Cook Inlet stations; C, 18, 25, 27, 28, 32, 33, 35, 37, 39, 49, 53, and 54.

Station 18 (Cook Inlet) *Macoma calcarea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	Number in Age Class
1	4.2						3
2	4.4	6.0					1
3	3.9	5.8	7.9				8
4	3.9	6.4	8.0	9.7			5
5	3.6	6.4	8.5	10.9	12.3		3
6	4.4	6.5	8.4	10.8	12.9	14.8	2
	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION						22

* M S L = Mean Shell Length, mm

Figure VI.C.41. Growth history of *Macoma calcarea* from Cook Inlet Station 18.

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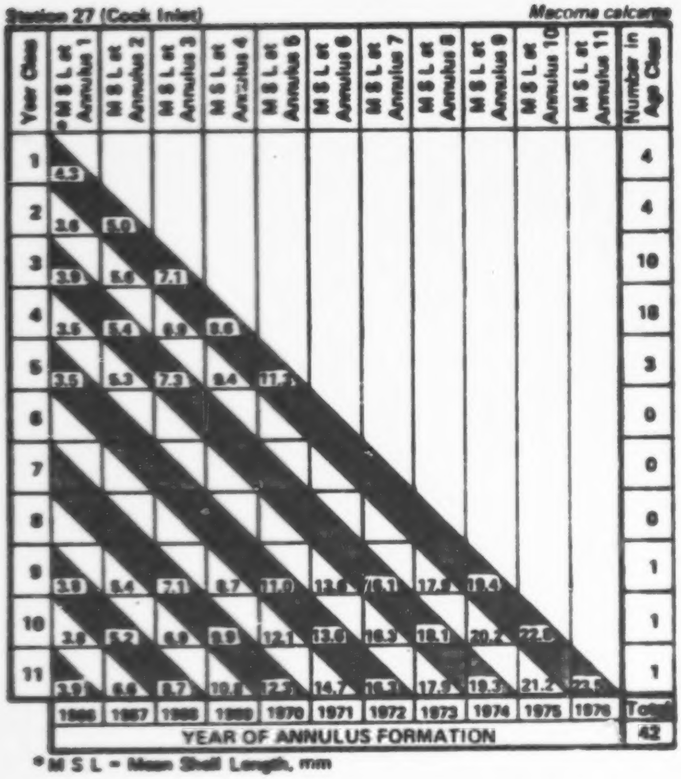
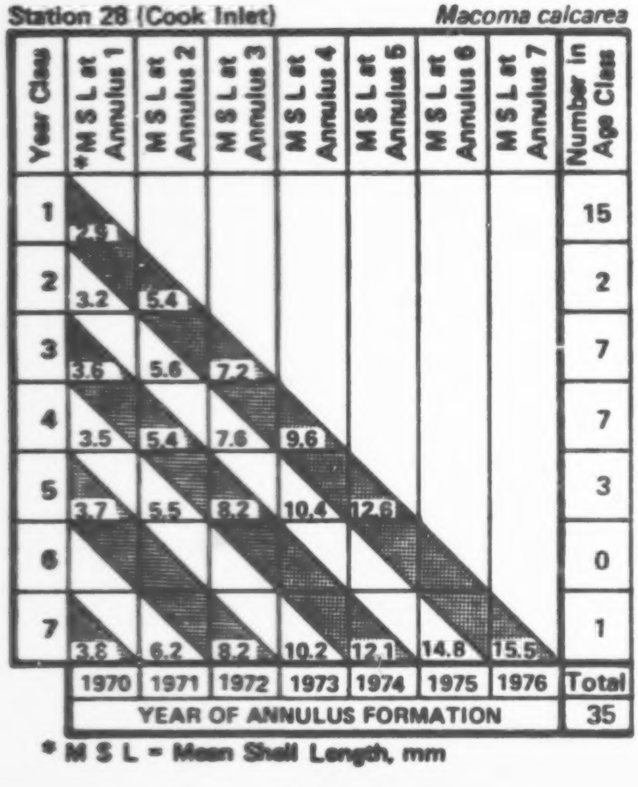


Station 27 (Cook Inlet) *Macoma calcarea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	Number in Age Class
1	4.3											4
2	3.8	5.0										4
3	3.9	5.6	7.1									10
4	3.5	5.4	6.9	8.8								18
5	3.5	5.3	7.3	9.4	11.5							3
6												0
7												0
8												0
9	3.8	5.4	7.1	8.7	11.0	13.6	16.1	17.9	19.4			1
10	3.8	5.2	6.9	8.9	12.1	13.6	16.3	18.1	20.2	22.0		1
11	3.9	6.6	8.7	10.8	12.5	14.7	16.5	17.9	19.3	21.2	23.5	1
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION											42

*M S L = Mean Shell Length, mm

Figure VI.C.42. Growth history of *Macoma calcarea* from Cook Inlet Station 27.



Station 28 (Cook Inlet) *Macoma calcarea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	Number in Age Class
1	2.9							15
2	3.2	5.4						2
3	3.6	5.6	7.2					7
4	3.5	5.4	7.6	9.6				7
5	3.7	5.5	8.2	10.4	12.6			3
6								0
7	3.6	6.2	8.2	10.2	12.1	14.8	15.5	1
	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION							35

* M S L = Mean Shell Length, mm

Figure VI.C.43. Growth history of *Macoma calcarea* from Cook Inlet Station 28.

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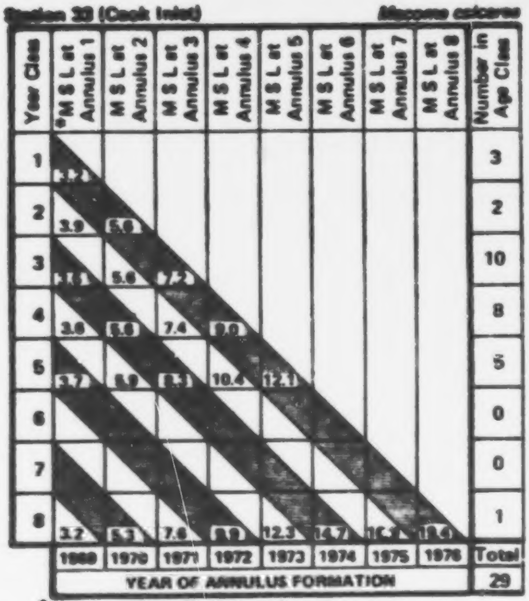
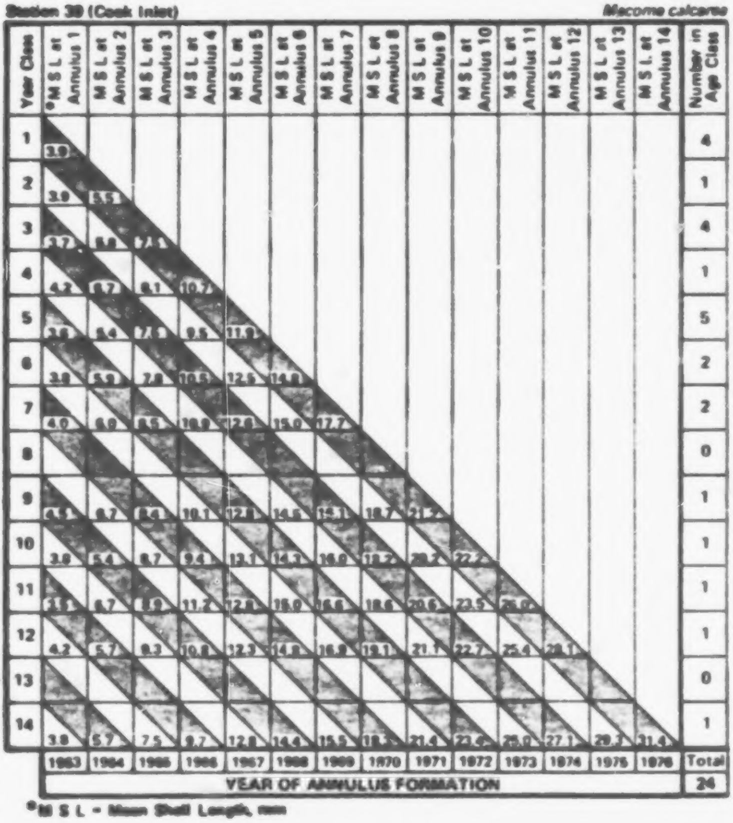


Station 33 (Cook Inlet) *Macoma calcarea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	Number in Age Class
1	[illegible]								3
2	3.9	5.6							2
3	[illegible]	5.6	7.2						10
4	3.8	5.8	7.4	9.0					8
5	3.7	5.9	8.1	10.4	12.1				5
6									0
7									0
8	3.2	5.3	7.6	9.9	12.3	14.7	[illegible]	18.4	1
	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION								29

*M S L - Mean Shell Length, mm

Figure VI.C.44. Growth history of *Macoma calcarea* from Cook Inlet Station 33.



Station 39 (Cook Inlet) *Macoma calcarea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	Number in Age Class
1	3.9														4
2	3.9	5.5													1
3	3.7	5.8	7.1												4
4	4.2	6.7	8.1	10.7											1
5	3.8	5.4	7.1	9.5	11.9										5
6	3.8	5.9	7.8	10.5	12.5	14.8									2
7	4.0	6.0	8.5	10.9	12.6	15.0	17.7								2
8															0
9	4.5	6.7	8.4	10.1	12.8	14.5	16.1	18.7	21.3						1
10	3.8	5.4	8.7	9.4	13.1	14.3	16.0	18.2	20.2	22.2					1
11	3.5	6.7	8.9	11.2	12.8	15.0	16.6	18.6	20.6	23.5	25.0				1
12	4.2	5.7	8.3	10.8	12.3	14.8	16.9	19.1	21.1	22.7	25.4	28.1			1
13															0
14	3.8	5.7	7.5	9.7	12.8	14.4	15.5	18.3	21.4	23.6	25.0	27.1	29.3	31.4	1
	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION														24

*M S L - Mean Shell Length, mm

Figure VI.C.45. Growth history of *Macoma calcarea* from Cook Inlet Station 39.

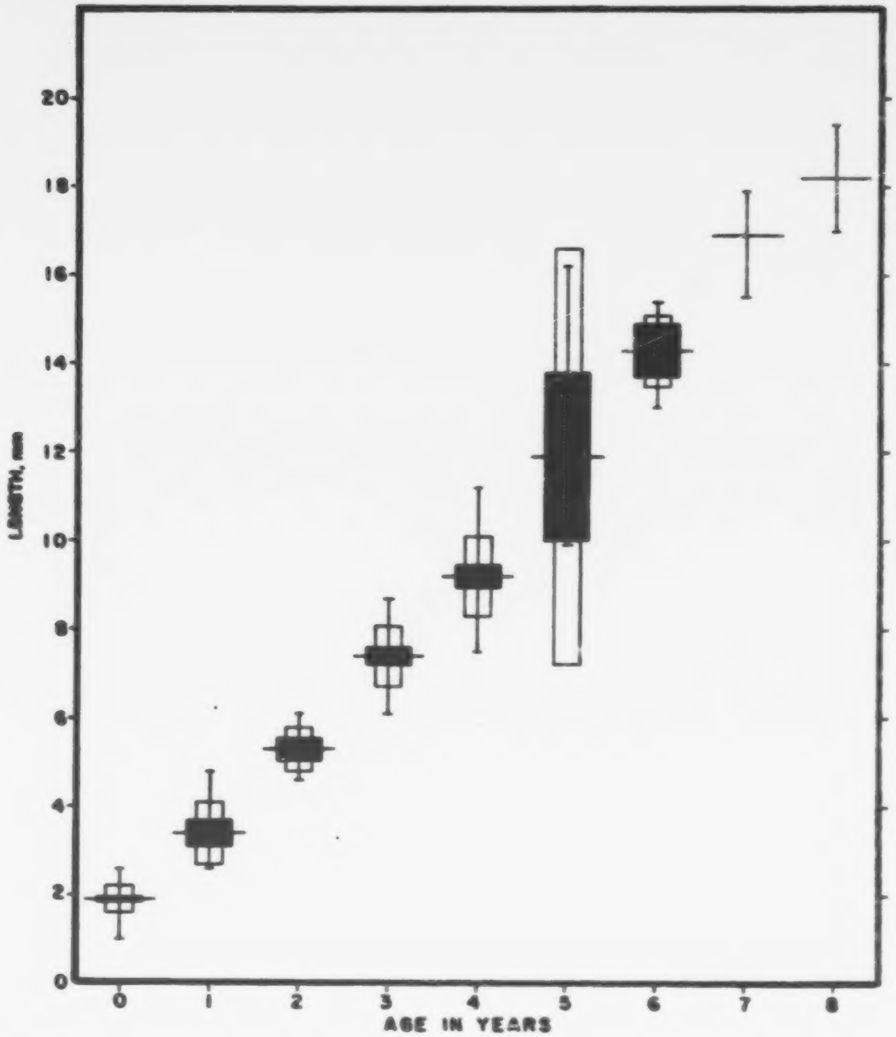


Figure VI.C.46. Growth curve for *Macoma calcarea* from thirteen Cook Inlet Stations; C, 18, 25, 27, 28, 32, 33, 35, 37, 39, 49, 53, and 54. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

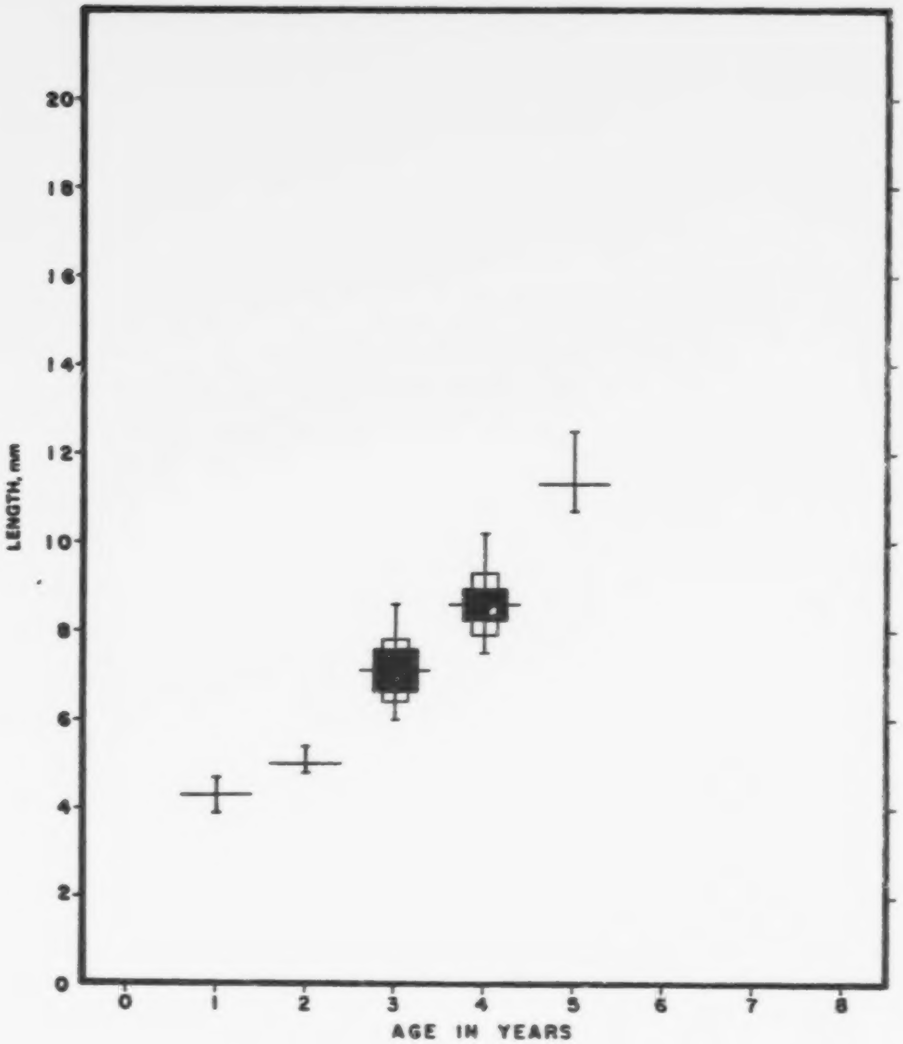


Figure VI.C.47. Growth curve for *Macoma calcarea* from Cook Inlet Station 27. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

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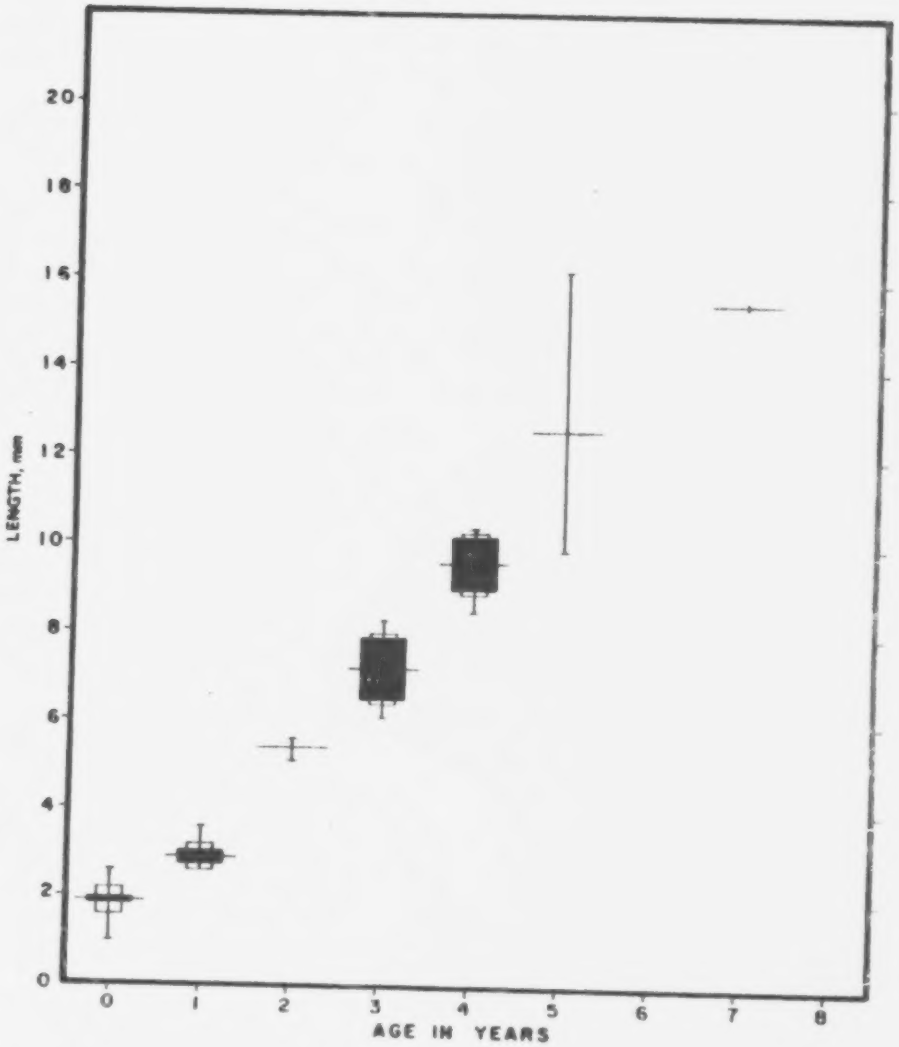

Figure VI.C.48. Growth curve for *Macoma calcarea* from Cook Inlet Station 28. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

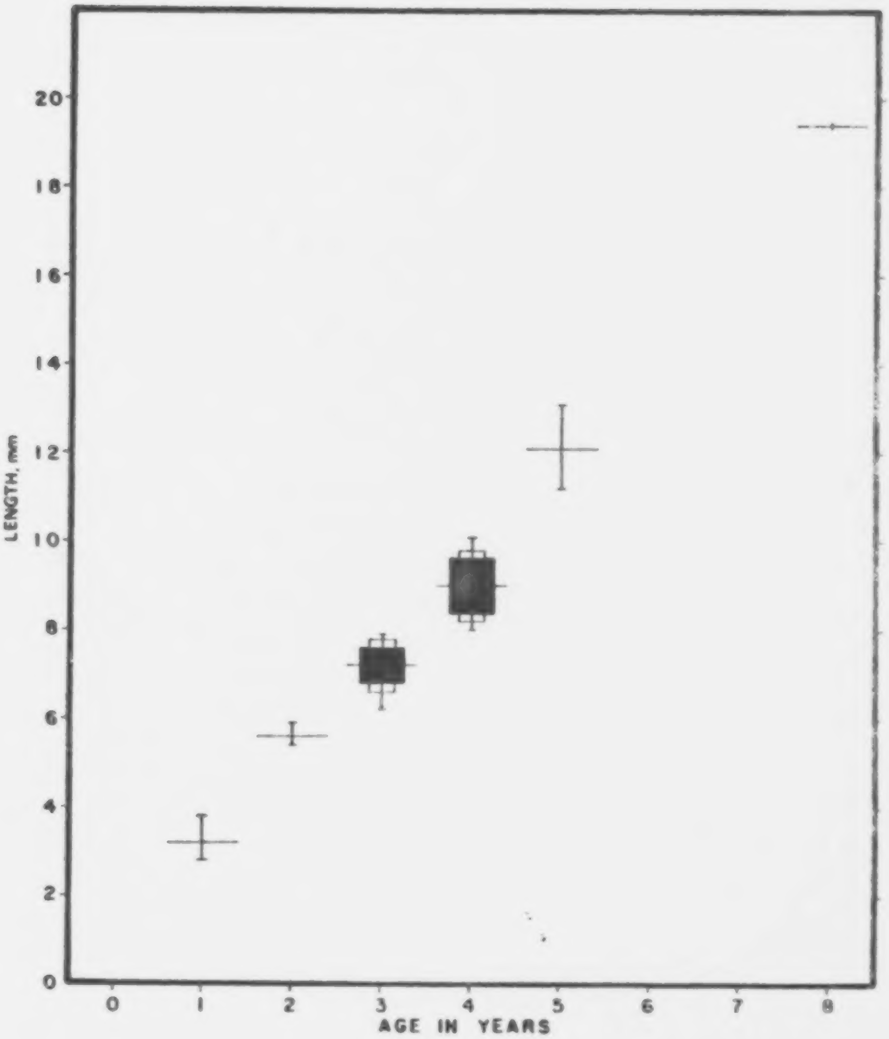

Figure VI.C.49. Growth curve for *Macoma calcarea* from Cook Inlet Station 33. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

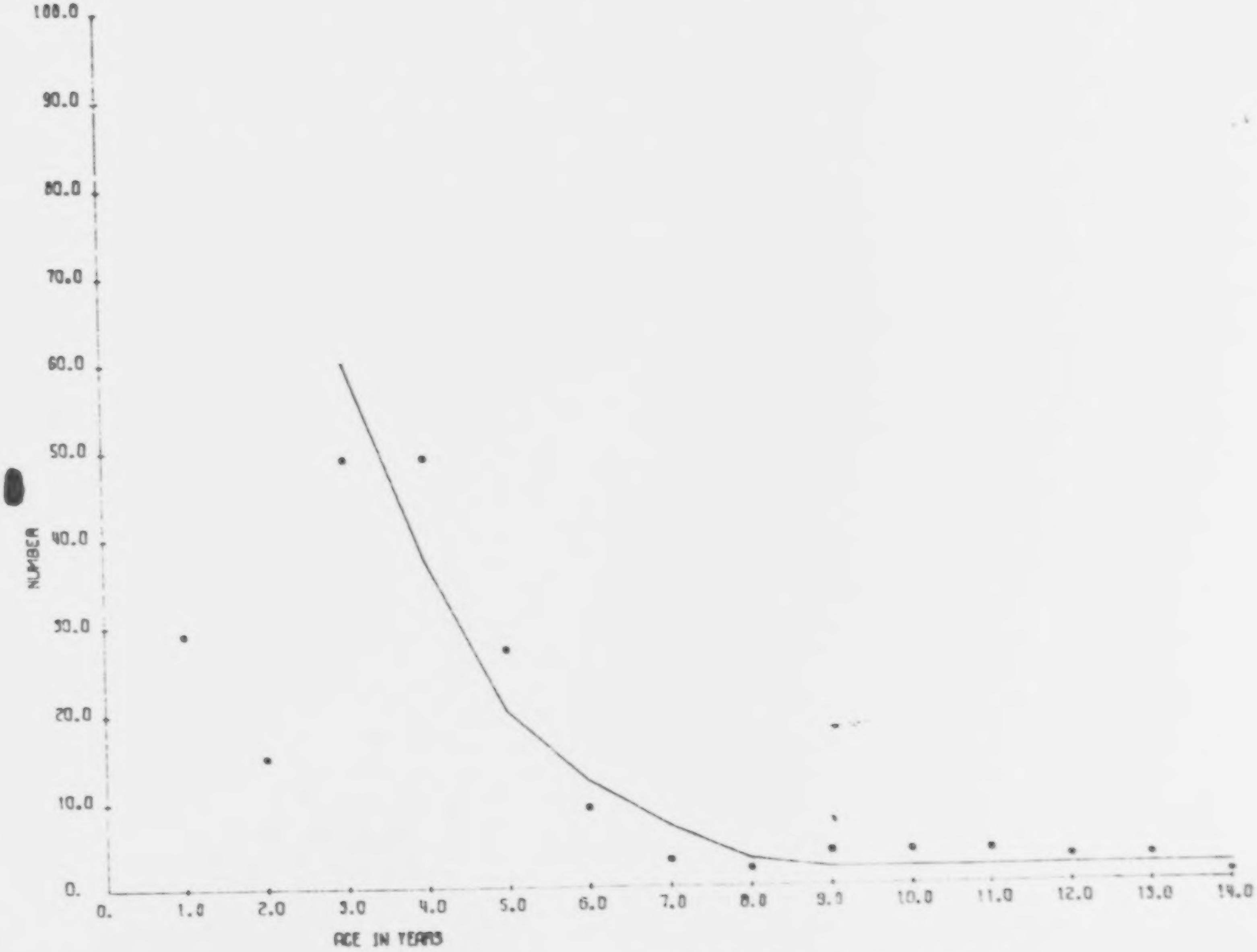

Figure VI.C.50. Graph of abundance vs. age for *Macoma calcarea* in Cook Inlet.

Tellina nuculoides

Tellina nuculoides was collected at the stations listed in Table VI.C.I and shown in Fig. VI.C.51. There was no apparent gear bias in the collection of *T. nuculoides*, and all age classes were well represented in the samples as shown in the age composition Table VI.C.LIII. Six hundred and seventy-two *T. nuculoides* were aged from nine stations; UW2, 30, 31, 40A, 41, 42, 44, 45, and 63. The annual increase in shell length for each of the size classes in Cook Inlet was typically 0.5 to 2.0 mm (Tables VI.C.LIII-VI.C.LVI; Figs. VI.C.52-VI.C.61). Growth was similar at all stations, and varied only slightly from year to year (Figs. VI.C.52-VI.C.57). The integrity of the age classes is suggested by Figs. VI.C.58 to VI.C.61 where it can be observed that none of the standard errors of the mean overlap. The mean shell lengths at each annular age showed some variation (Figs. VI.C.52-VI.C.57). However, 326 of the 336 values for mean shell lengths at an annulus (Figs. VI.C.52-VI.C.57) did not exceed the standard deviation around that mean annular length by more than 1 mm (Tables VI.C.LIII-VI.C.LVI).

The majority of the 672 specimens examined were between 5 and 10 years of age. However, there was considerable variation in the age composition of the collections (Tables VI.C.LIII-VI.C.LVI). For example, 71% of the *Tellina nuculoides* from Station UW2 were in the 1 year class, while 78% of the clams from Station 44 were between 5 and 8 years of age. The oldest and largest *T. nuculoides* collected were 13 years of age and 16.4 mm in length, respectively.

Dry weights of the various age classes are available in Table VI.C.LVII. Biomass estimations (dry tissue weight) for each age class were made for *Tellina nuculoides* at Stations 30, 31, 42, 44, and 63. Total *T. nuculoides* biomass at these stations ranged from 0.23 to 5.27 g/m^2 (Tables VI.C.LVIII-VI.C.LXII).

Approximately 13% mortality occurred in the sixth year class of *Tellina nuculoides*, this gradually increased to 80% by age 12 (Table VI.C.LXIII; Fig. VI.C.62). Calculations using the age composition Tables VI.C.LIII to VI.C.LVI indicate that extensive mortality occurred after 8 years of age, 89% of the clams were from 0 to 8 years of age. There was uneven annual recruitment to year classes 0 through 6 (Tables VI.C.LIII and VI.C.LXIII). Therefore, mortality estimates could only be made for clams older than 5 years. However, it is obvious that *T. nuculoides* is relatively long lived in Cook Inlet. Mortality rates did not reach the 50% level until age nine (Table VI.C.LXIII; Fig. VI.C.62). The gradual increase of mortality rates with age and the large number of older individuals in the population suggests that senescence, rather than periodic environmental stress or predation, is a prime source of mortality. This hypothesis is supported by the low frequency of occurrence with which this species was found in the stomachs of the common crustacean predators (see Section B). No comparable mortality data are available for this species from other regions of the Gulf of Alaska.

TABLE VI.C.LIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA NUCULOIDES* FROM LOWER COOK INLET FROM NINE STATIONS
(UW2, 30, 31, 40A, 41, 42, 44, 45, and 63)
(See Table VI.C.I and Fig. VI.C.47)

N = Number of clams; ML = Mean length of clams; SD = Standard deviation; SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	14	2.3	0.2	0.11	2.1-2.7
1	70	3.6	0.4	0.09	2.8-4.5
2	20	5.4	0.6	0.28	4.7-6.8
3	43	7.5	1.0	0.30	6.0-10.6
4	47	8.8	1.1	0.31	6.7-12.3
5	95	10.2	1.5	0.30	7.5-13.9
6	120	10.7	1.3	0.23	7.8-14.1
7	112	11.4	1.3	0.24	9.1-14.6
8	79	12.4	1.4	0.31	9.6-15.6
9	38	12.8	1.3	0.41	10.4-15.7
10	20	13.5	1.4	0.66	11.6-16.2
11	11	14.2	1.4	0.91	12.2-16.3
12	2	15.0	0.6	1.24	14.6-15.4
13	1	16.4	0.0	0.00	16.4
	Total = 672				

TABLE VI.C.LIV

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA NUCULOIDES* FROM LOWER COOK INLET STATION 42

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	5	5.2	0.4	0.41	4.7-5.7
3	15	7.9	1.0	0.55	6.7-10.6
4	28	8.9	1.3	0.52	6.7-12.3
5	47	10.3	1.6	0.46	8.1-13.9
6	54	10.9	1.5	0.40	8.2-14.1
7	52	11.6	1.5	0.41	9.1-14.6
8	41	12.8	1.6	0.49	9.6-15.6
9	22	13.2	1.4	0.63	10.4-15.7
10	10	14.3	1.3	0.90	12.2-16.2
11	9	14.6	1.3	0.95	12.2-16.3
12	2	15.0	0.6	1.24	14.6-15.4
13	1	16.4	0.0	0.00	16.4
	Total = 286				

TABLE VI.C.LV

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA NUCULOIDES* FROM LOWER COOK INLET STATION 44

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	2	6.0	0.9	1.86	5.4-6.6
3	22	7.4	1.0	0.45	6.0-10.0
4	10	9.1	0.8	0.54	7.9-10.7
5	33	10.3	1.5	0.51	7.5-12.5
6	55	10.7	1.2	0.32	7.8-13.6
7	49	11.4	1.1	0.31	9.8-14.4
8	34	12.1	1.1	0.37	10.1-14.2
9	10	12.3	1.2	0.82	10.5-14.3
10	2	13.4	2.6	5.37	11.6-15.2
11	2	12.6	0.1	0.21	12.5-12.7
	Total = 219				

TABLE VI.C.LVI

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA NUCULOIDES* FROM LOWER COOK INLET STATION UW2

N = Number of clams; ML = Mean length of clams; SD = Standard deviation;
SEM = Standard error of the mean; R = Range

Year class (Age of clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	14	2.3	0.2	0.11	2.1-2.7
1	67	3.6	0.4	0.10	2.8-4.3
2	9	5.2	0.4	0.29	4.8-5.9
3	2	7.0	0.1	0.21	6.9-7.1
4	0	--	--	--	--
5	2	10.3	0.0	0.00	10.3
	Total = 94				

TABLE VI.C.LVII

AGE AND DRY-WEIGHT RELATIONSHIPS OF COOK INLET *TELLINA NUCULOIDES*

Age	Number of Clams	Total Dry Weight (g)*	$\bar{x}$ Total Dry Weight (g)	Total Shell Weight (g)	Total Dry Tissue Weight (g)	$\bar{x}$ Dry Tissue Weight (g)	% Dry Tissue†
0	84	0.225	0.0027	0.190	0.035	0.0004	15.6
1	25	0.259	0.0104	0.236	0.023	0.0009	8.9
2	31	0.865	0.0279	0.758	0.107	0.0035	12.4
3	25	1.221	0.0488	1.089	0.132	0.0053	10.8
4	28	2.222	0.0794	2.025	0.197	0.0070	8.9
5	26	3.063	0.1178	2.770	0.293	0.0113	9.6
6	25	4.311	0.1724	3.944	0.367	0.0147	8.5
7	25	5.839	0.2336	5.337	0.502	0.0201	8.6
8	26	6.843	0.2632	6.366	0.477	0.0183	7.0
9	15	4.584	0.3056	4.102	0.482	0.0321	10.5
10	13	5.251	0.4039	4.802	0.449	0.0345	8.6
11	9	4.160	0.4622	3.730	0.430	0.0478	10.3
12	2	1.123	0.5615	0.990	0.133	0.0665	11.8

*Total dry weight = total shell weight + total dry tissue weight

†% dry tissue = $\frac{\text{total dry tissue weight}}{\text{total dry weight}} \times 100$

TABLE VI.C.LVIII

TELLINA NUCULOIDES: BIOMASS ESTIMATIONS PER m^2 AT STATION 30

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0004	0
1	0	0	0.0009	0
2	0	0	0.0035	0
3	0	0	0.0053	0
4	2	4	0.0070	0.0280
5	1	2	0.0113	0.0226
6	0	0	0.0147	0
7	2	4	0.0201	0.0804
8	1	2	0.0183	0.0366
9	1	2	0.0321	0.0642
Total dry tissue weight in g(biomass)/m^2				0.2318

*See Table VI.C.LVII

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TABLE VI.C.LIX

TELLINA NUCULOIDES: BIOMASS ESTIMATIONS PER m^2 AT STATION 31

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0004	0
1	0	0	0.0009	0
2	3	6	0.0035	0.0210
3	1	2	0.0053	0.0106
4	1	2	0.0070	0.0140
5	4	8	0.0113	0.0904
6	6	12	0.0147	0.1764
7	4	8	0.0201	0.1608
Total dry tissue weight in g(biomass)/m^2				0.4732

*See Table VI.C.LVII

TABLE VI.C.LX

TELLINA NUCULOIDES: BIOMASS ESTIMATIONS PER m^2 AT STATION 42

Age	Number in 6 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0004	0
1	0	0	0.0009	0
2	2	3	0.0035	0.0105
3	3	5	0.0053	0.0265
4	3	5	0.0070	0.0350
5	10	17	0.0113	0.1921
6	18	30	0.0147	0.4410
7	19	32	0.0201	0.6432
8	13	22	0.0183	0.4026
9	13	22	0.0321	0.7062
10	2	3	0.0345	0.1035
11	1	2	0.0478	0.0956
Total dry tissue weight in g(biomass)/m^2				2.6562

*See Table VI.C.LVII

TABLE VI.C.LXI

TELLINA NUCULOIDES: BIOMASS ESTIMATIONS PER m^2 AT STATION 44

Age	Number in 6 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0004	0
1	0	0	0.0009	0
2	2	3	0.0035	0.0105
3	22	37	0.0053	0.1961
4	9	15	0.0070	0.1050
5	29	48	0.0113	0.5424
6	52	87	0.0147	1.2789
7	47	78	0.0201	1.5678
8	30	50	0.0183	0.9150
9	7	12	0.0321	0.3852
10	1	2	0.0345	0.0690
11	1	2	0.0478	0.0956
Total dry tissue weight in g(biomass)/m^2				5.1655

*See Table VI.C.LVII

TABLE VI.C.LXII

TELLINA NUCULOIDES: BIOMASS ESTIMATIONS PER m^2 AT STATION 63

Age	Number in 5 Grabs	$\bar{x}$ Number of Clams/m^2	$\bar{x}$ Dry Tissue Weight (g)*	Dry Tissue Weight (g)/m^2
0	0	0	0.0004	0
1	0	0	0.0009	0
2	0	0	0.0035	0
3	2	4	0.0053	0.0212
4	2	4	0.0070	0.0280
5	4	8	0.0113	0.0904
6	4	8	0.0147	0.1176
7	4	8	0.0201	0.1608
8	3	6	0.0183	0.1098
9	5	10	0.0321	0.3210
10	7	14	0.0345	0.4830
Total dry tissue weight in g(biomass)/m^2				1.3318

*See Table VI.C.LVII

TABLE VI.C.LXIII

THE NUMBER OF *TELLINA NUCULOIDES* AT EACH AGE, AND THE RELATIONSHIP BETWEEN AGE AND NATURAL MORTALITY IN LOWER COOK INLET

Age (t)	Number at Age from Original Data (N)	Number at Age from Curve in Figure VI.C.62*	Natural Mortality % from Curve in Figure VI.C.62*	Mortality Coefficient (z)
0	14	-	-	-
1	70	-	-	-
2	20	-	-	-
3	43	-	-	-
4	47	-	-	-
5	95	-	-	-
6	120	120	13	.1335
7	112	105	16	.1823
8	79	88	26	.2973
9	38	65	54	.7732
10	20	30	57	.8360
11	11	13	62	.9550
12	2	5	80	1.6094
13	1	1		

*Based on the technique of Gruffydd (1974) in which the number at age from the curve for six-year old clams is estimated. All other numbers at age are calculated using the following expression:

$$N_{t+1} = N_t \cdot e^{-z(t)}; \text{ where}$$

N = number of clams
z = mortality coefficient
t = time
t + 1 = time at the next year
e = 2.718

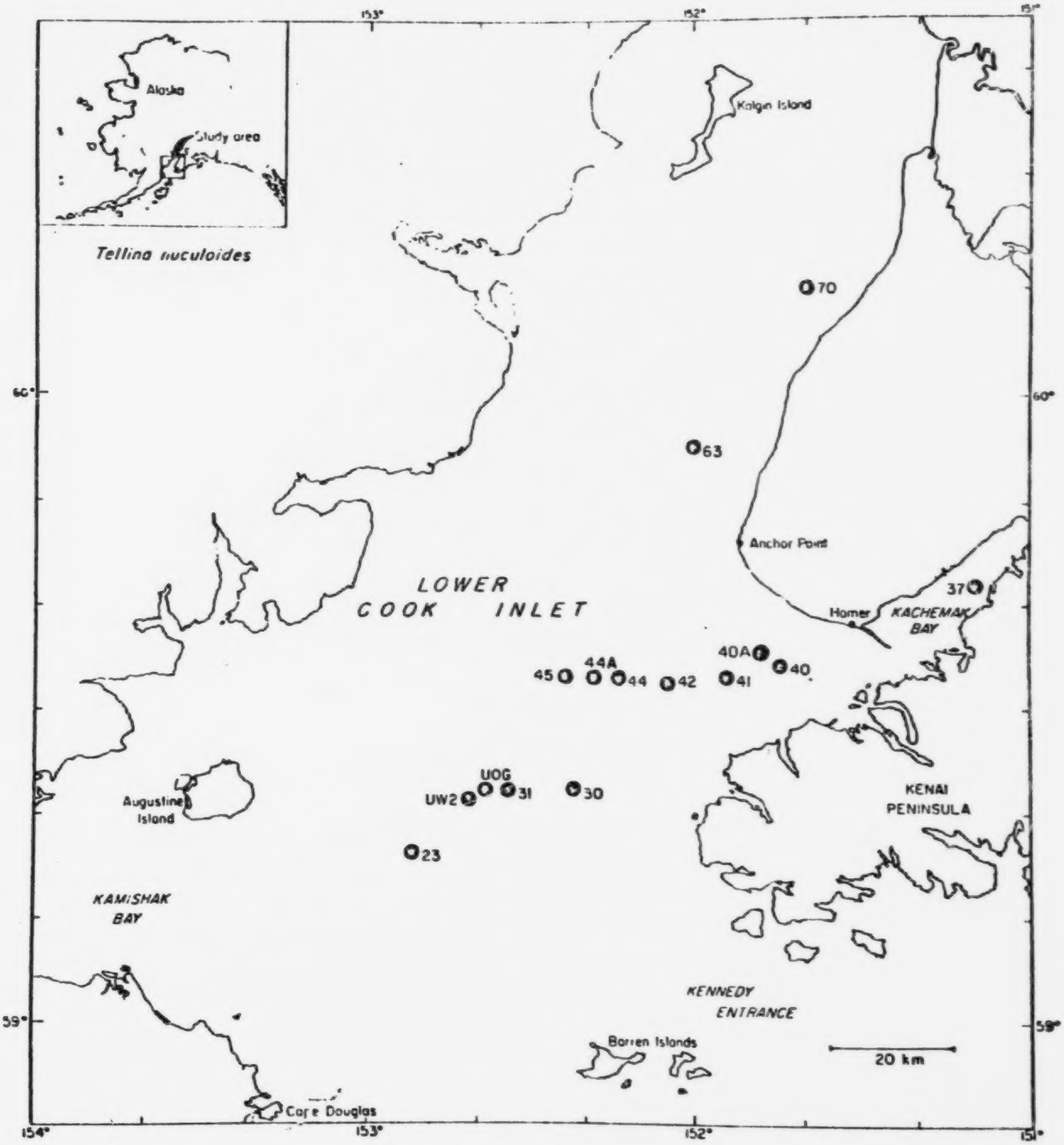
TABLE VI.C.LXIV

A COMPARISON OF MEAN SHELL LENGTH AT AGE FOR FOUR SPECIES OF CLAMS FROM VARIOUS REGIONS OF ALASKA

N = number of clams, ML = mean shell length in mm

	Nucula tenuis						*Nuculana fossa*						*Spisula polynyma*						*Macoma calcarea*					
	Bering Sea*		Bering Sea**		Cook Inlet†		Bering Sea*		Bering Sea**		Cook Inlet†		Prince Wm Sound††		Bering Sea§		Cook Inlet†		Bering Sea*		Bering Sea**		Cook Inlet†	
Age	N	ML	N	ML	N	NL	N	ML	N	ML	N	ML	N	ML	N	ML	N	ML	N	ML	N	ML	N	ML
0	10	1.0	102	1.4	30	1.7	15	1.3	1	2.5	119	2.1	0	-	0	-	1	5	4	2.0	1	2.1	318	1.9
1	27	1.5	121	2.2	55	2.3	69	4.4	37	4.0	67	3.7	9	8	0	-	128	10	78	4.1	45	4.3	29	3.4
2	110	3.9	79	3.5	44	3.3	112	6.8	37	6.0	97	6.7	0	13	4	12	117	15	70	6.4	286	6.4	15	5.3
3	57	5.3	84	4.8	34	4.3	43	9.1	75	8.6	88	9.0	4	22	9	28	175	21	29	10.7	281	8.2	49	7.4
4	39	6.9	45	6.0	30	5.3	20	12.4	76	10.9	60	10.9	2	32	42	35	56	26	24	16.9	200	10.2	49	9.2
5	25	9.3	27	7.2	7	6.2	33	16.1	30	12.8	106	12.9	0	43	39	48	1	38	11	17.9	110	12.9	27	11.9
6	8	13.7	30	8.5	0	-			16	14.2	60	14.0	0	57	17	57	1	43			10	15.6	9	14.3
7			31	10.0	2	9.3			32	17.0	6	16.2	4	66	18	69	0	-			0	-	3	16.9
8			11	10.5					11	18.4			11	77	18	78	1	82			1	20.7	2	18.2
9			5	12.3					6	19.9			17	88	51	85	3	80			1	25.1	4	20.1
10													26	98	91	94	5	92			0	-	4	22.4
11													39	108	133	101	16	98			1	48.8	4	24.2
12													46	115	121	108	16	107						
13													44	122	71	114	14	112						
14													62	127	34	121	14	114						
15													25	133	3	123	4	120						
16													9	139	1	127	4	118						
Totals	276		535		202		292		321		603		298		652		556		216		936		513	

* Neiman (1964)
**Feder *et al.* (1979)
† Present report
††Feder *et al.* (1976)
§ Feder *et al.* (1978)



153°
152°
151°
154°
60°
59°
Alaska
Study area
Tellina nuculoides
Kalgin Island
70
63
Anchor Point
37
Homer
KACHEMAK BAY
LOWER COOK INLET
40A
40
44A
45
44
42
41
UOG
UW2
31
30
Augustine Island
23
KENAI PENINSULA
KAMISHAK BAY
KENNEDY ENTRANCE
Barren Islands
20 km
Cape Douglas

Figure VI.C.51. Distribution map of all *Tellina nuculoides* collected by van Veen grab and pipe dredge from lower Cook Inlet stations.

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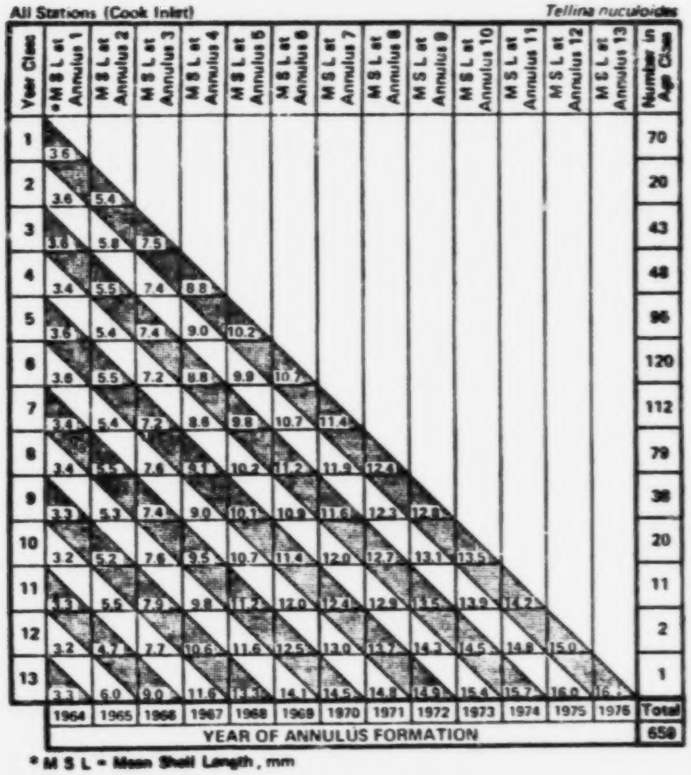
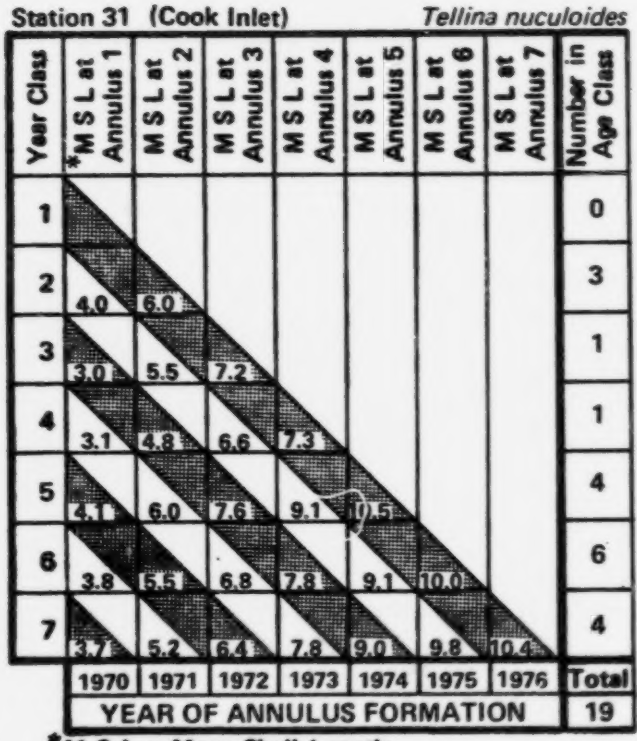


All Stations (Cook Inlet) *Tellina nuculoides*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	Number in Age Class
1	3.6													70
2	3.6	5.4												20
3	3.6	5.8	7.5											43
4	3.4	5.5	7.4	8.8										48
5	3.6	5.4	7.4	9.0	10.2									96
6	3.6	5.5	7.2	8.8	9.9	10.7								120
7	3.4	5.4	7.2	8.6	9.8	10.7	11.4							112
8	3.4	[illegible]	7.6	[illegible]	10.2	11.2	11.9	12.4						79
9	3.3	5.3	7.4	9.0	10.1	10.9	11.6	12.3	12.8					38
10	3.2	5.2	7.6	9.5	10.7	11.4	12.0	12.7	13.1	13.5				20
11	3.3	5.5	7.9	9.8	11.2	12.0	12.4	12.9	13.5	13.9	14.2			11
12	3.2	4.7	7.7	10.6	11.6	12.5	13.0	13.7	14.3	14.5	14.8	15.0		2
13	3.3	6.0	9.0	11.6	[illegible]	14.1	14.5	14.8	14.9	15.4	15.7	16.0	[illegible]	1
	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION													650

*M S L = Mean Shell Length, mm

Figure VI.C.52. Growth history of *Tellina nuculoides* from nine Cook Inlet stations; UW2, 30, 31, 40A, 41, 42, 44, 45, and 63.



Station 31 (Cook Inlet) *Tellina nuculoides*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	Number in Age Class
1								0
2	4.0	6.0						3
3	3.0	5.5	7.2					1
4	3.1	4.8	6.6	7.3				1
5	4.1	6.0	7.6	9.1	10.5			4
6	3.8	5.5	6.8	7.8	9.1	10.0		6
7	3.7	5.2	6.4	7.8	9.0	9.8	10.4	4
	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION							19

*M S L = Mean Shell Length

Figure VI.C.53. Growth history of *Tellina nuculoides* from Cook Inlet Station 31.

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Station 42 (Cook Inlet) *Tellina nuculoides*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	Number in Age Class
1														0
2	3.3	5.2												5
3	3.5	6.0	7.9											15
4	3.3	5.6	7.5	8.9										28
5	3.6	5.4	7.4	9.0	10.3									47
6	3.5	5.5	7.3	9.0	10.1	10.9								54
7	3.1	5.5	7.3	8.7	9.9	10.9	11.6							52
8	3.5	5.6	7.7	9.3	10.5	11.5	12.2	12.8						41
9	3.3	5.5	7.8	9.3	10.4	11.7	12.0	12.7	13.2					22
10	3.4	5.4	8.0	10.2	11.4	12.0	12.7	13.3	13.8	14.3				10
11	3.3	5.6	8.3	10.3	11.6	12.3	12.7	13.2	13.8	14.2	14.6			9
12	3.2	4.7	7.7	10.6	11.6	12.5	13.0	13.7	14.3	14.5	14.8	15.0		2
13	3.1	6.0	9.0	11.6	13.3	14.1	14.5	14.8	14.9	15.4	15.7	16.0	16.4	1
	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION													286

*M S L = Mean Shell Length

Figure VI.C.54. Growth history of *Tellina nuculoides* from Cook Inlet Station 42.

Station 44 (Cook Inlet) *Tellina nuculoides*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	Number in Age Class
1												0
2	3.9	6.0										2
3	3.6	5.8	7.4									22
4	3.5	5.6	7.7	9.1								10
5	3.6	5.4	7.4	9.1	10.3							33
6	3.6	5.5	7.3	8.7	9.9	10.7						55
7	3.5	5.3	7.3	8.8	9.9	10.8	11.4					49
8	3.4	5.4	7.4	9.0	10.1	10.9	11.6	12.1				34
9	3.3	5.0	6.9	8.7	9.8	10.6	11.2	11.8	[illegible]			10
10	3.5	5.6	7.9	10.1	11.3	11.8	12.3	12.8	13.1	13.4		2
11	3.4	4.8	6.2	7.7	9.4	10.5	11.1	11.6	11.9	12.2	12.6	2
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION											219

*M S L = Mean Shell Length

Figure VI.C.55. Growth history of *Tellina nuculoides* from Cook Inlet Station 44.

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Station 63 (Cook Inlet) *Tellina nuculoides*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	Number in Age Class
1											0
2											0
3	3.6	4.9	6.4								2
4	3.2	4.1	6.0	7.1							2
5	3.7	5.0	6.6	7.8	8.8						4
6	3.3	4.9	6.4	7.7	8.8	9.6					4
7	3.6	5.3	6.4	7.6	8.6	9.4	10.3				4
8	3.6	5.1	6.9	8.4	9.5	10.4	11.0	11.7			3
9	3.6	5.3	6.9	8.5	9.7	10.5	11.3	11.8	12.2		5
10	3.0	5.0	7.2	8.9	9.9	10.9	11.4	11.6	12.3	[illegible]	7
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION										31

*M S L = Mean Shell Length

Figure VI.C.56. Growth history of *Tellina nuculoides* from Cook Inlet Station 63.

Station UW2 (Cook Inlet) *Tellina nuculoides*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	Number in Age Class
1	3.6					67
2	3.6	5.2				9
3	3.9	5.6	7.0			2
4						0
5	4.1	5.7	8.0	9.7	10.3	2
	1972	1973	1974	1975	1976	Total
	**Y A F					80

*M S L = Mean Shell Length

**Y A F = Year of Annulus Formation

Figure VI.C.57. Growth history of *Tellina nuculoides* from Cook Inlet Station UW2.

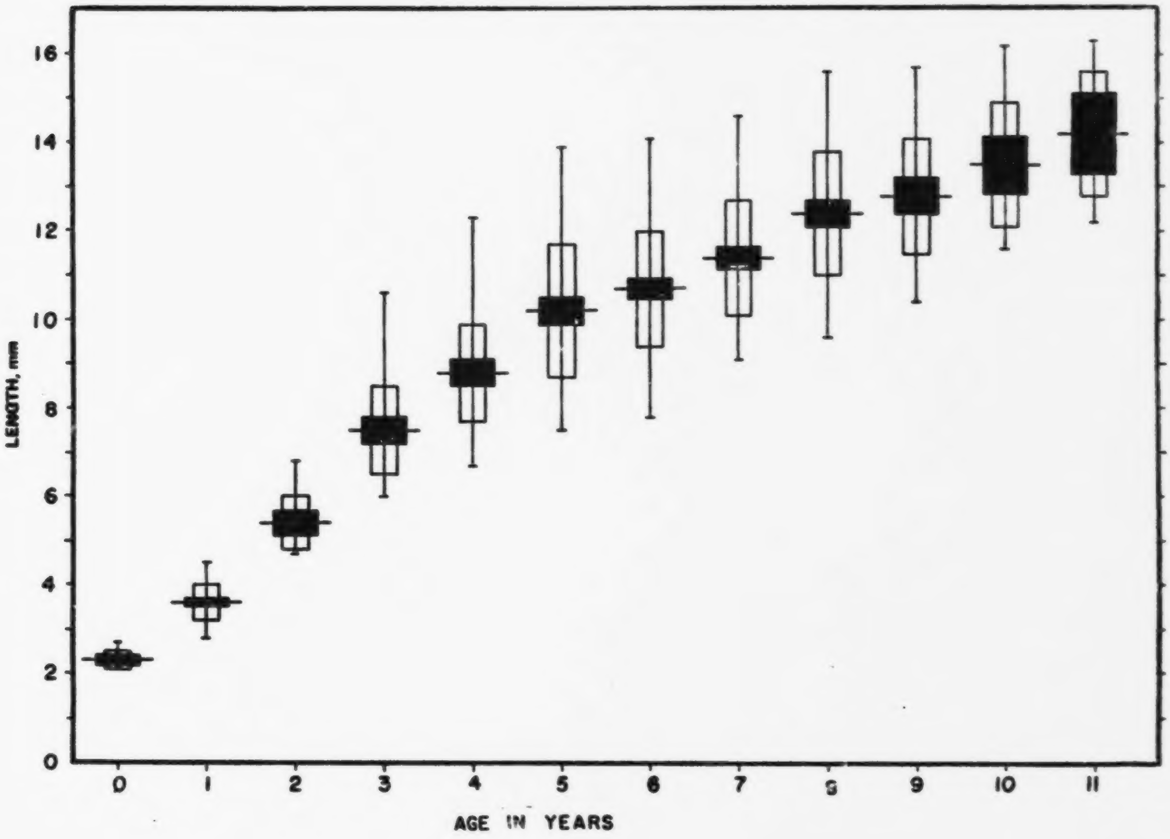

Figure VI.C.58. Growth curve for *Tellina nuculoides* from nine Cook Inlet stations; UW2, 30, 31, 40A, 41, 42, 44, 45, and 63. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

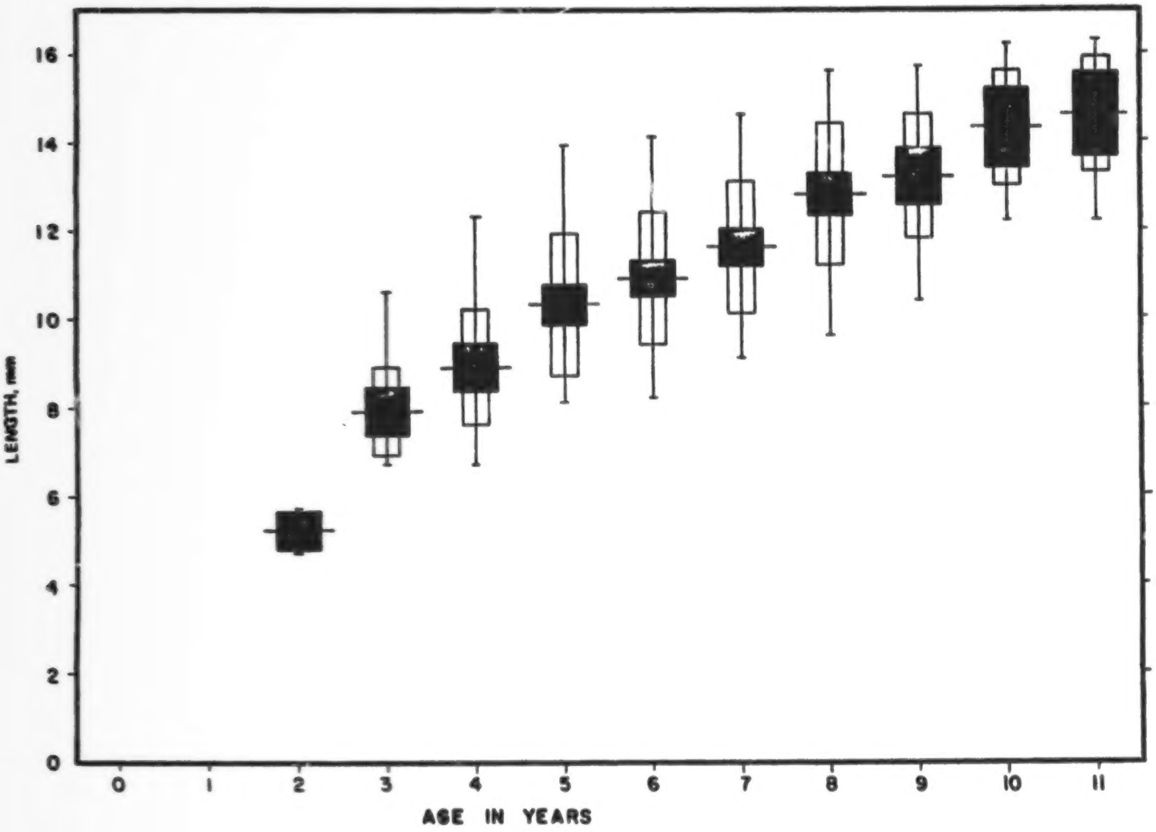

Figure VI.C.59. Growth curve for *Tellina nuculoides* from Cook Inlet Station 42. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

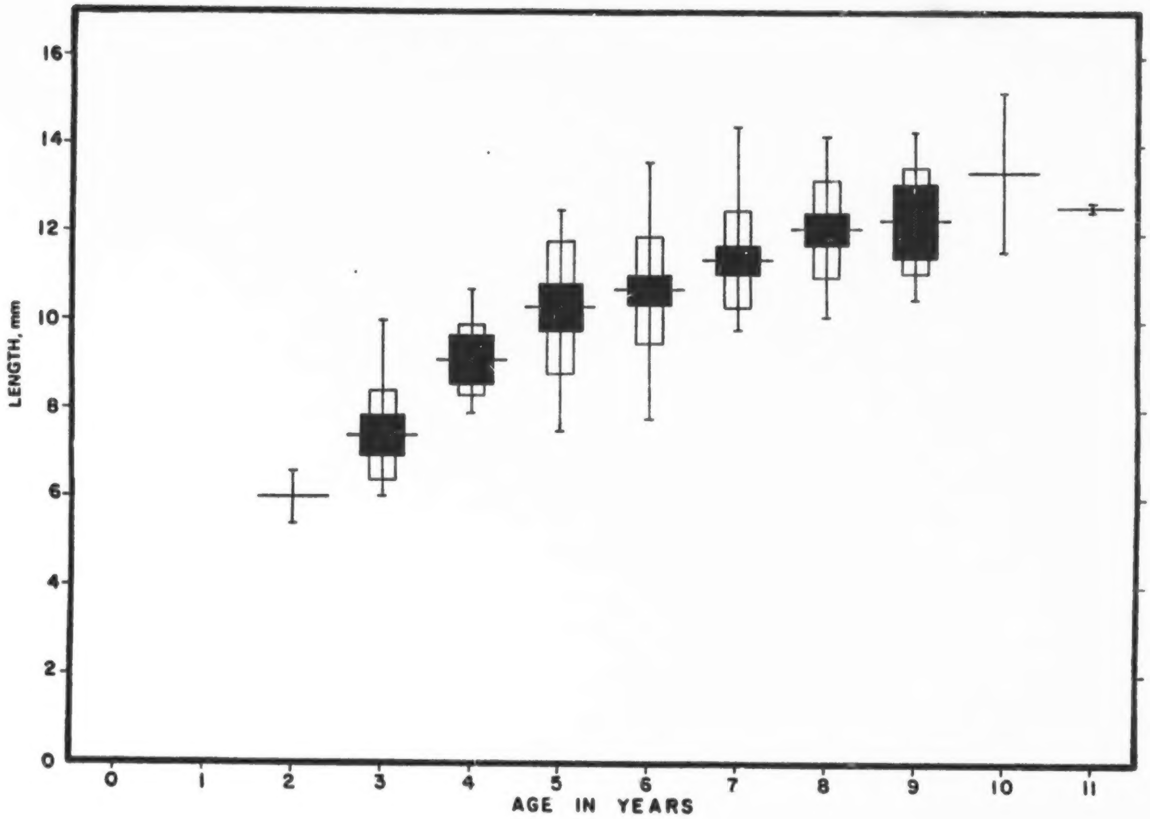

Figure VI.C.60. Growth curve for *Tellina nuculoides* from Cook Inlet Station 44. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

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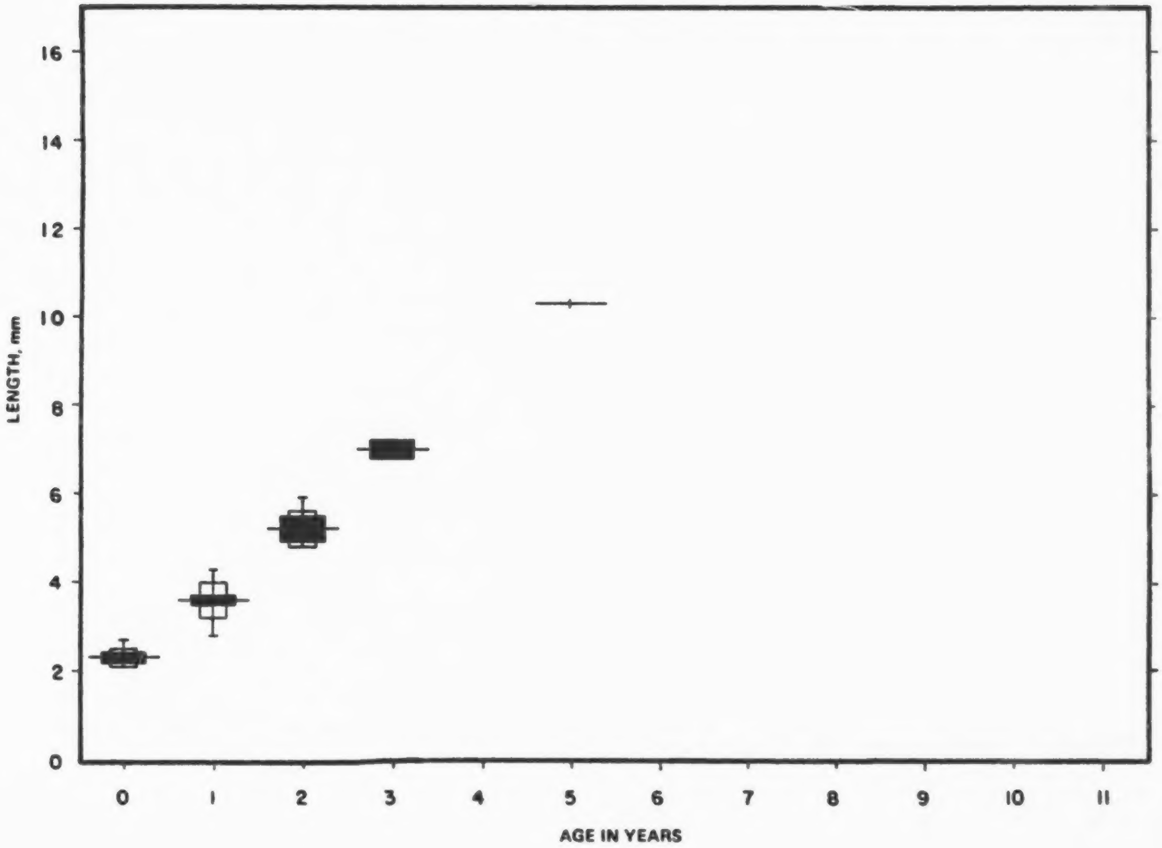


Figure VI.C.61. Growth curve for *Tellina nuculoides* from Cook Inlet Station UW2. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the black box, and range by the vertical line.

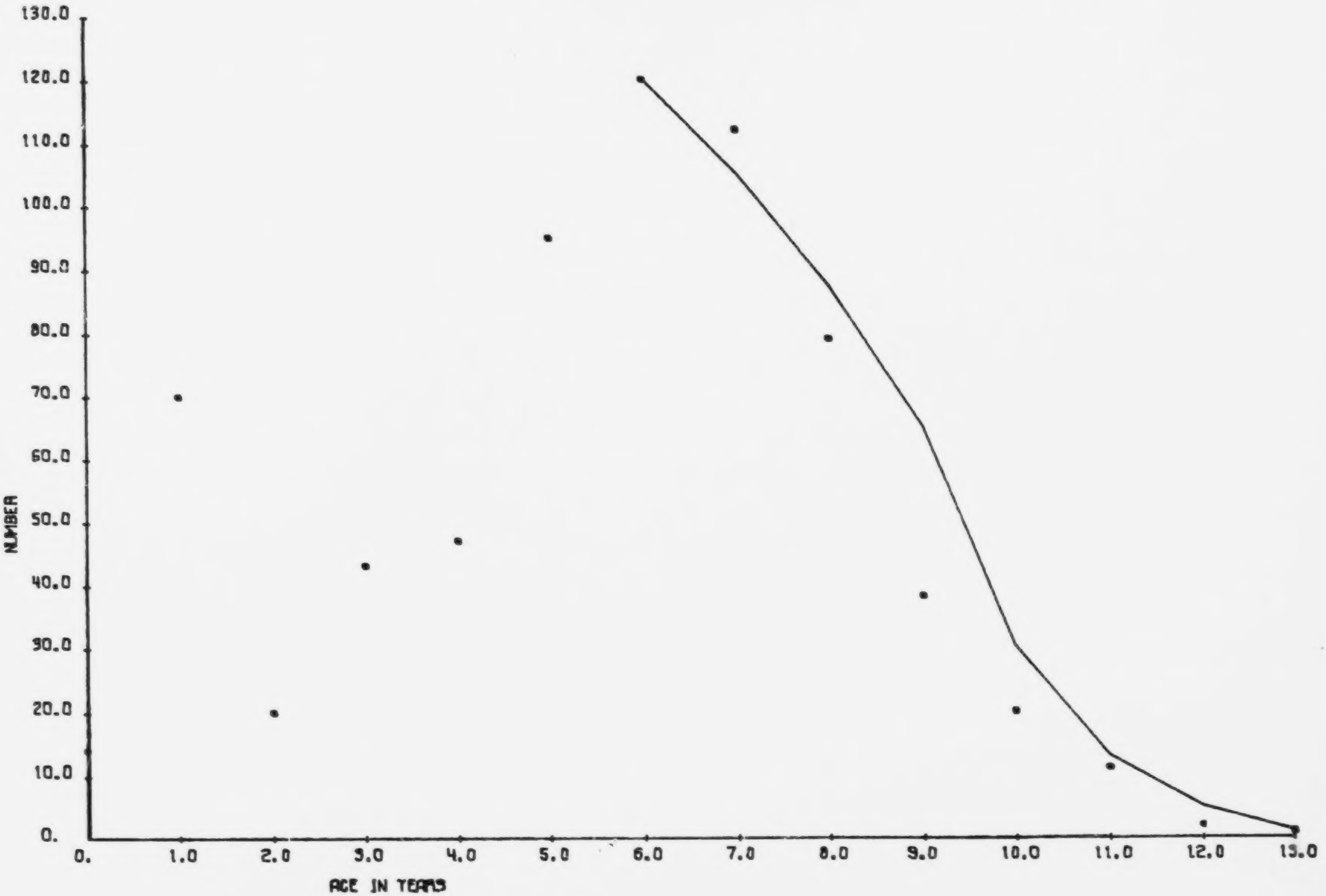


Figure VI.C.62. Graph of abundance vs. age for *Tellina nuculoides* in Cook Inlet.

SECTION D - IMPORTANT HABITATS FOR BIOLOGICALLY IMPORTANT INVERTEBRATES

Major concentrations of snow crabs (*Chionoecetes bairdi*) were found primarily in the western part of lower Cook Inlet in all surveys. In terms of numbers, the largest catches using the try-net in 1977 and 1978, occurred at Stations 5 (111 crab per km fished), 25 (100 per km fished), A53 (50 per km fished), 8 (43 per km fished), 18 (17 per km fished), A62 (15 per km fished), and 27 (11 per km fished) (Table VI.D.I). At all other stations in the Inlet, the average number captured in all trawls was less than 10 per km fished. In Kachemak Bay, snow crabs were most abundant at Stations 41 and 40 with an average of 8 and 5 snow crabs per km fished (Table VI.D.I). See Feder *et al.* (1978) for distribution maps of the following dominant lower Cook Inlet epifaunal species collected in 1976; *Chionoecetes bairdi*, *Hyas lyratus*, *Oregonia gracilis*, *Paralithodes camtschatica*, *Pagurus ochotensis*, *Elassochirus tenuimanus*, *Crangon dalli*, *Neptunea lyrata*, *Fusitriton oregonensis*, *Echinarachnius parma*.

The size distribution data for snow crabs (Table VI.D.II) indicate that the areas sampled are inhabited by size segregated populations. Snow crabs less than 20 mm carapace width were encountered primarily near the mouth of the Inlet and lower Kamishak Bay. Station 5 was the area where these small crabs were most abundant ranging from 7 to 414 per km fished. Station 8 (4 to 135 per km fished) and 25 (8 to 238 per km fished) also had significant numbers of these young crabs (Table VI.D.II). The size frequency of these small snow crab at Station 8 is presented in Table VI.D.III. The size distribution data suggest the existence of a nursery area for snow crabs that encompasses Stations 5, 6, 7, 8, 18, 23, 25, 53, A53 (Table VI.D.II), and other nearby stations not sampled. Stations 6 and 23 are in the current lease area and the other stations, with the exception of 53 and A53, are directly in the path of prevailing currents which flow southward over the lease area. The absence of snow crabs less than 20 mm carapace width in the Kachemak Bay area is puzzling since the area supports a commercial fishery. Their absence in Kachemak Bay may be due to recruitment failure, or perhaps crabs move from the nursery area described above or from other nursery areas not discovered, to Kachemak Bay and other parts of the Inlet. Further observations on the distribution of these small crabs are necessary to determine the importance of nursery areas as a source of recruitment to Cook Inlet and the adjacent Gulf of Alaska.

The trawl contents at Stations 5 through 8, where juvenile snow crabs are most abundant (Table VI.D.II and VI.D.IV), are dominated by small sponges intermixed with hydroid fragments, polychaete tubes, and crustacean and mollusc fragments. The most common polychaete tubes associated with the sponges are those of *Spiochaetopterus typicus*. After removing all motile organisms the composition of the remaining material by per cent weight and volume is as follows:

	Wet Weight (%)	Volume (%)
Sponge	70	67
Hydroid and worm tubes	12	14
Hydroids	6	6
Crustaceans and mollusc fragments	12	13
Totals	100	100

A variety of infaunal and epifaunal species are associated with the sponge aggregate (see Table VI.D.IV and Section A).

Low numbers of sub-adult crabs 21 to 80 mm carapace widths, were encountered at all snow crab study stations (Table VI.D.II). Perhaps snow crabs of this size range inhabit shallow waters not sampled. It is essential to know where this important size group of crab is located if the dynamics of this important species and its potential interaction with oil is to be comprehended. Information on the highest observed abundance of snow crab, all sizes included, are presented in Table VI.D.V).

Female snow crabs with eggs constituted significant percentages of the catches at the following stations on the west side of the Inlet: Station 62 (20%), PMEL 1 (12%), 54 (13%), 53 (4%), and 23 (4%) (see Table VI.D.I). Near the mouth of the Inlet at Station 6, 17% of the snow crabs captured were females with eggs. In Kachemak Bay 25% to 69% of the snow crabs captured were females with eggs (pooled data from trawls November 1977 to August 1978). These areas must be considered critical habitats because moulting success of snow crabs and survival of their zoeae are negatively affected by crude oil (Rice *et al.*, 1976). No newly moulted females or females with hatching eggs were collected during the study period 1977-78 (see ADF&G, 1976 for data on migration, moulting and mating in snow crabs).

On the west side of lower Cook Inlet king crabs were most abundant at Stations 35 (20 per km fished), and 27 (8 per km fished; see Table VI.D.I). No king crabs were captured near the mouth of the Inlet in 1977 or 1978, although they were collected at Stations A5, 6, and 8 in 1976. In Kachemak Bay, king crabs were most abundant at Stations 43 (30 per km fished), 39 (16 per km fished), A40 (9 per km fished) and 40 (2 per km fished). In both Kamishak Bay and Kachemak Bay in excess of 20% of all king crab captured were females with eggs (Table VI.D.I). Juvenile king crab did not make up a significant portion of any of the catch at the stations sampled. Over 95% of the king crabs captured were sexually mature individuals. No "pods" of juveniles were encountered. Soft-shell male king crabs were encountered in March at Station 41, in May at Station 54, and June at Station PMEL 7. One grasping pair was captured in March at Station 55. Soft-shell females were observed at Station 53 in June and July, and Station 35 in June. By June, the majority of the crabs captured had new carapaces. (See ADF&G, 1976 for data on migration, moulting, and mating in king crabs).

Dungeness crab were captured with regularity at Stations 40 (13 per km fished), A40 (8 per km fished), and 41 (6 per km fished; see Table VI.D.I). Females with eggs constituted 19%, 2%, and 3%, respectively, of the catch at these same stations. In August, 64 Dungeness crab with carapace widths of 22 to 45 mm were captured at Station A40. The remainder of the Dungeness crab captured were generally over 100 mm in carapace width. In non-quantitative trawls taken in June, 99% (n = 45) of the mature females examined had egg clutches. In July, only one female (n = 36) with eggs was observed. Kachemak Bay must be considered as the most important habitat for Dungeness crab in Cook Inlet (see ADF&G 1976 for data on migration, moulting, and mating in Dungeness crab. Distribution data for dominant species is also included in Section A.

The pink shrimp (*Pandalus borealis*) was encountered in the greatest abundance at Station 37, inner Kachemak Bay, where catches for all trawls in 1977 and 1978 averaged 926 per km fished (Table VI.D.VI). Highest concentrations in outer Kachemak Bay were observed at Station 227 (278 per km fished), PMEL 7 (202 per km fished) and 40 (167 per km fished). At Station 62, near the mouth of Chinitna Bay, 123 per km fished were encountered. No areas where pink shrimp were abundant were observed in Kamishak Bay. Near the mouth of the Inlet at Stations 5, 6, and 8, pink shrimp were observed at average population densities of 9, 11, and 35 per km fished. The results of the survey indicate Kachemak Bay to be the major habitat for pink shrimp in Cook Inlet. In terms of weight, pink shrimp maximum catches occurred in inner Kachemak Bay, Station 37 (Table VI.D.V). (See ADF&G, 1976 for data on migration and reproductive biology of pandalid shrimps).

Humpy shrimp (*Pandalus goniurus*) was most abundant at Station 56 in northern Kamishak Bay with an average of 792 per km fished (Table VI.D.VI). In the same area, Stations A62 and A56, the average number captured was 275 and 125 per km fished, respectively. The greatest weights of humpy shrimp also occurred at A62 and A56 (Table VI.D.V). Near the mouth of the Inlet, 166 humpy shrimp were captured per km fished. In the Kachemak Bay area, humpy shrimp were most abundant at Stations 38 (301 per km fished), A38 (224 per km fished), and 37 (171 per km fished) all in the inner Bay. The numbers of humpy shrimp encountered at the mid-Kachemak Bay stations were 0 to 24 per km fished. Based on this survey the critical habitats for humpy shrimp are nothern Kamishak Bay, Chinitna Bay, and inner Kachemak Bay.

Coonstripe shrimp (*Pandalus hypsinotus*) was most abundant in inner Kachemak Bay. At Stations 37, 38, and A38 catches of coonstripe shrimp averaged 176, 41 and 71 per km fished. Smaller numbers, 4 to 30 per km fished, were observed in outer Kachemak Bay. No large concentrations of coonstripe shrimp were observed at any of the other stations examined in Cook Inlet (Table VI.D.VI). Table VI.D.V contains catch data by weight; the maximum catch, 947 g per km fished, was taken at Station 37.

Sidestripe shrimp (*Pandalopsis dispar*) was also most abundant, an average of 15 per km fished, in inner Kachemak Bay Sation 37. The maximum weight, 309 g per km fished of this species was also taken at Station 37

(Table VI.D.V). Average catches of less than 10 per km fished were made in outer Kachemak Bay Stations PMEL 7, 39, and Station 8 near the mouth of the Inlet (Table VI.D.VI). Catch data in g per km appears in Table VI.D.V.

Distribution of the zoeae of the commercially important crustaceans has been determined by Dr. T. English (Figs. VI.D.2-VI.D.5). The distribution of late zoeae are similar to the benthic stages captured by trawls (see Section A and Table VI.D.V for benthic distributional data).

The following organisms, non-commercially harvested species, were often among the dominant invertebrates in trawl samples (Table VI.D.V; Fig. VI.D.1). Weights of the sea pen, *Ptilosarcus gurneyi*, in mid-Kachemak Bay were highest at Stations 40 (5,181 g per km fished) and 227 (2,591 g per km fished). The sea pen was also common at PMEL 4 (1,969 g per km fished) in the central zone of the Inlet. The snail, *Neptunea lyrata*, was most prevalent at Stations 35 and 36 (1,443 g per km fished) in Kamishak Bay, Station 8 (1,088 g per km fished) in the outer Inlet, and Station 42 (1,567 g per km fished) in Kachemak Bay. *Crangon dalli* has a wide distribution but the greatest weights were generally in upper Kamishak Bay (999 g per km fished, Station 36; 872 g per km fished, Station 56). *Crangon communis* was most abundant in upper Kamishak Bay with 2,062 g per km fished captured at Station 62, and 459 g per km fished at Station 8 in the outer region of the Inlet. Crangonids are important food resources for snow crab and several bottom-feeding fishes (see Section B). The sand dollar, *Echinarachnius parma*, was found primarily in Kachemak Bay, with greatest numbers observed at Stations A40 and A45 with weights of 2,073 g and 3,866 g per km fished, respectively. *Cucumaria fallax* was an important component of benthic invertebrate biomass in Kachemak Bay with the greatest weights being 47,148 g per km fished (Station A40) and 28,992 g per km fished (Station 42). The greatest biomass of the sea urchin, *Strongylocentrotus droebachiensis*, was recorded at the Kachemak Bay Station 55 (16,058 g per km fished) and 42 (5,340 g per km fished).

TABLE VI.D.I

MEAN NUMBER AND PERCENT OVIGEROUS KING, SNOW AND DUNGENESS CRABS CAPTURED IN ALL QUANTITATIVE TRAWLS IN 1977 AND 1978 IN LOWER COOK INLET

$\bar{x}$ = Mean, km = Kilometers, - = No specimens collected

Station	King crab		Snow crab		Dungeness crab	
Cook Inlet	$\bar{x}$/km fished	% of catch w/eggs	$\bar{x}$/km fished	% of catch w/eggs	$\bar{x}$/km fished	% of catch w/eggs
5	-	-	111	>1	1	-
6	-	-	6	17	-	-
8	-	-	43	>1	1	1
18	2	33	17	0	1	0
23	1	50	4	4	-	-
25	-	-	100	>1	-	-
27	8	39	11	8	-	-
28	-	-	5	0	-	-
35	20	7	8	0	-	-
36	1	0	22	3	-	-
A36	-	-	10	0	-	-
B36	2	0	34	0	-	-
37	2	50	3	7	3	0
38	-	-	2	0	-	-
A38	-	-	1	0	-	-
39	16	40	2	0	-	-
40	2	38	5	4	13	19
A40	9	20	1	25	8	2
41	1	20	8	69	6	3
B41	1	0	5	0	-	-
B43	29	18	-	-	-	-
A47	-	-	1	0	-	-
49	-	-	42	0	-	-
A49	-	-	6	0	-	-
Bluff	-	-	21	0	-	-
53	2	78	8	4	-	-
A53	2	50	50	1	-	-
54	2	33	7	13	-	-
55	2	0	-	-	-	-
56	-	-	7	5	-	-
A56	-	-	5	0	-	-
62	-	-	16	20	-	-
A62	-	-	15	2	-	-
B62	-	-	1	0	-	-
204	-	-	6	0	-	-
227	-	-	3	0	2	0
PME1	-	-	11	12	-	-
PME7	1	0	4	0	1	0

TABLE VI.D.II

SIZE DISTRIBUTION OF *CHIONOECETES BAIRDI* FROM SELECTED TRAWLS FROM COOK INLET STATIONS

DATA FROM ALL QUANTITATIVE TRAWLS 1977 AND 1978

Data recorded as number of crabs; - = Not sexed

Station	5-20 mm	21-80 mm	81+ mm	No. Male/Female Crabs >81 mm	Comments
5	1469	16	27	15/12	Large crabs have fungus growth
6	7	0	5	3/2	
7	>300	-	-	-	
8	248	0	2	2/0	
18	44	0	14	-	
23	22	0	3	-	
25	396	-	2	-	
A40	0	2	2	1/1	
41	0	1	79	7/37	Most crabs were old shell covered with barnacles
53	81	2	30	14/4	
A53	92	0	13	1/12	
A62	32	1	105	48/57	

TABLE VI.D.III

JUVENILE SNOW CRAB CARAPACE WIDTHS, STATION 8, COOK INLET, ALASKA

10 May, 1978		7 June, 1978	
Width (mm)	Number	Width (mm)	Number
3	1	-	-
5	3	-	-
6	2	-	-
7	30	-	-
8	17	8	6
9	3	9	6
10	24	10	4
11	81	11	17
12	34	12	14
13	4	-	-
14	11	14	6
15	24	15	21
16	22	16	21
17	17	17	4
18	4	18	1
19	1	19	2
20	4	20	4
21	6	21	4
22	8	22	6
23	10	23	1
24	5	24	2
25	6	-	-

Total = 436

TABLE VI.D.IV

FAUNA ASSOCIATED WITH JUVENILE SNOW CRAB AT STATION 8, COOK INLET

Taxonomic Name	Counts		Weights (grams)	
	per km	per m^2	per km	per m^2
Eunephtya rubiformis	1.0	0.00028	5.2	0.00141
Eunoe depressa	1.0	0.00028	1.0	0.00028
Gattyana ciliata	22.7	0.00620	12.4	0.00338
Gattyana cirrosa	49.5	0.01353	1.0	0.00028
Anaitides mucosa	1.0	0.00028	2.1	0.00056
Typosyllis spp.	253.6	0.06933	1.0	0.00028
Potamilla neglecta	21.6	0.00592	1.0	0.00028
Sabella spp.	16.5	0.00451	1.0	0.00028
Crucigera zygophora	28.9	0.00789	2.1	0.00056
Chlamys rubida	12.4	0.00338	43.3	0.01184
Cyclocardia spp.	2.1	0.00056	1.0	0.00028
Hiatella arctica	2.1	0.00056	1.0	0.00028
Fusitriton oregonensis	43.3	0.01184	473.2	0.12936
Buccinum plectrum	13.4	0.00366	186.6	0.05101
Beringius kennicotti	3.1	0.00085	9.3	0.00254
Neptunea lyrata	23.7	0.00648	1087.6	0.29733
Gastropteron pacificum	2.1	0.00056	1.0	0.00028
Tritonia spp.	9.3	0.00254	1.0	0.00028
Nymphon grossipes	45.4	0.01240	1.0	0.00028
Cyclopoida				
Balanus hesperius	1.0	0.00028	2.1	0.00056
Balanus rostratus	13.4	0.00366	18.6	0.00507
Rocinela spp.	3.1	0.00085	1.0	0.00028
Ampelisca macrocephala	24.7	0.00676	2.1	0.00056
Ampeliscida eschrichti	7.2	0.00197	1.0	0.00028
Anonyx nugax	35.1	0.00958	5.2	0.00141
Stegocephalus inflatus	20.6	0.00564	3.1	0.00085
Decapoda	103.1	0.02818	28.9	0.00789
Pandalus spp.	1.0	0.00028	2.1	0.00056
Pandalus borealis	34.0	0.00930	42.3	0.01155
Pandalus platyceros	150.5	0.04115	116.5	0.03185
Sinorontocaris spina	9.3	0.00254	2.1	0.00056
Lebbeus groenlandica	2.1	0.00056	1.0	0.00028
Eualus barbata	4.1	0.00113	2.1	0.00056
Eualus suckleyi	2.1	0.00056	1.0	0.00028
Eualus townsendi	4.1	0.00113	1.0	0.00028
Eualus avina	143.3	0.03917	22.7	0.00620
Heptacarpus spp.	1.0	0.00028	1.0	0.00028
Crangon communis	2376.3	0.64961	918.6	0.25111
Argis dentata	23.7	0.00648	20.6	0.00564
Pagurus aleuticus	8.2	0.00225	187.6	0.05129
Labidochirus splendescens	24.7	0.00676	27.8	0.00761
Oregonia gracilis	106.2	0.02903	144.3	0.03946
Hyas lyratus	159.8	0.04368	479.4	0.13105

TABLE VI.D.IV

CONTINUED

Taxonomic Name	Counts		Weights (grams)	
	per km	per m^2	per km	per m^2
Chionoecetes bairdi	449.4	0.12286	505.0	0.13824
Laqueus californianus	2.1	0.00056	1.0	0.00028
Terebratalia spp.	1.0	0.00028	1.0	0.00028
Synoicidae	24.7	0.00676	218.6	0.05975
Icelinus borealis	-	-	1.0	0.00028
Psychrolutes paradoxus	-	-	10.3	0.00282
*Asterotheca alascana**	-	-	7.2	0.00197

*Many empty worm tubes of *Spiochaetopterus* and small sponges were also present but not counted. There was 0.5 kg sponge, hydroid and *Spiochaetopterus* present in the trawl.

TABLE VI.D.V

DISTRIBUTION OF DOMINANT ORGANISMS TAKEN BY A TRAWL WITH A 3.6 METER MOUTH OPENING IN COOK INLET.
DATA ARE PRESENTED AS MAXIMUM CATCH AT A STATION, (1) IN GRAMS PER KILOMETER FISHED AND (2) AS GRAMS PER METER SQUARE

Station*	*Ptilonareus gurneyi*	*Neptunea lyrata*	*Pandalus borealis*	*Pandalus hypsinotus*	*Pandalus goniurus*	*Pandalopsis dispar*	*Crangon dalli*	*Crangon communis*	*Paralithodes camtschatica*	*Chionoecetes bairdi*	*Cancer magister*	*Echinarachnius parma*	*Cucumaria fallax*	*Strongylocentrotus droebachiensis*
Grams per km fished														
5		275	12		P	P	5	P		1443			155	P
6			18				18			9				
8		1088	130		363		466	459		181				
18		67					52		777	1285	P			P
23									P	381		21		
25	13	39			10		371			381				
27	10	928					549	P	P	1979				
28		83					31			1249				
35	P	1443		5	149		560	P	P	2422				
36		724		38	227		999		1250	1178				
A36		P			P		P			P				
B36		1433					569		P	P				
37		772	7772	974	672	309	304	67	2435	2098	P			
38			62	383	160		41	7		188				
A38		16		590	335		10			21				
39		47	144	292	63	151	129	28	P	801				
40	5181	93	1088	96	31		125	P	2332	1264	11176	104	155	
A40	P	130		P			311		299	1	2990	2073	47148	120
B40		41							639				19299	678
41	26	P	6				207		P	9062	2443	1036	4560	
B41							223		639	347		7		
42	P	1567										1057	28992	5340
A43		278							39010			175	9605	1897
44													P	
A45												3866		
A47	P									P		P		
49	49	967			66		293			275				
A49	P				P		P			P				
51					1533		516		989	3489				
52					P		P			P				
53	P	5					110	P	P	443				
A53	P	522					228		P	P		14	928	2646
54		171			23		670		1370	685				
55		89		16					P				3003	16058
56		231		P	31		872			357				
A56					1607		P			P				430
C56		141		16			93							809
62			495					2062		P				722
A62		P			2528		237			21				
B62			3				330			165		165		
BLUFF	P	P								P				P
PMEL 1	P	292					77			1821		2		
PMEL 4	69	31					5					907		
PMEL 7	42	113	1865	107	46	61	105		503	1854	725			
204		98					285			674				
227	2591	62	850	8	18		207		415	373	1161			
350			P			P		P		P				P
358														P
E 1**					839		62			P				
F 2**	516				21		69		650	347				
NE 1**	P	P		P	1792				P	P				
NE 2**		P			1083				P	P				
NE 3**		P			490					306				
N 1**				P	6429					P				
N 2**					463265					P				
N 3**					46327				P	P				

TABLE VI.D.V
CONTINUED

Station*	*Ptilosarcus gurneyi*	*Neptunea lyrata*	*Pandalus borealis*	*Pandalus hypsinotus*	*Pandalus goniurus*	*Pandalopsis dispar*	*Crangon dalli*	*Crangon communis*	*Paralithodes camtschatica*	*Chionoecetes bairdi*	*Cancer magister*	*Echinarachnius parma*	*Cucumaria fallax*	*Strongylocentrotus drobachiensis*
Grams per m^2														
5		0.07515	0.00327		P	P	0.00132	P						P
6			0.00496				0.00496			0.00255				
8		0.29733	0.03541		0.09915		0.12748	0.12555		0.04958				
18		0.01841					0.01416		0.21247	0.35128	P			P
23									P	0.10411		0.00567		
25	0.00354	0.01062			0.00283		0.10146			0.10411				
27	0.00282	0.25365					0.15014	P	P	0.54111				
28		0.02266					0.00850			0.34136				
35	P	0.39456		0.00133	0.04064		0.15298	P	P	0.66201				
36		0.19791		0.01034	0.06206		0.27300		0.34172	0.32214				
A36		P			P		P			P				
B36		0.39174					0.15557		P	P				
37		0.21097	2.12466	0.26629	0.18375	0.08455	0.08314	0.01841	0.66573	0.57366	P			
38			0.01704	0.10467	0.04363		0.01123	0.00187		0.05149				
A38		0.00423		0.16121	0.09159		0.00282			0.00564				
39		0.01275	0.03946	0.07976	0.01719	0.04133	0.03523	0.00752	P	0.21889				
40	1.41644	0.02550	0.29745	0.02630	0.00850		0.03414	P	0.63740	0.34561	3.05527	0.02833	0.04249	
A40	P	0.03561		P			0.08499		0.08173	0.00014	0.81730	0.56658	12.88895	0.03288
B40		0.01127							0.17473				5.27583	0.18526
41	0.00708	P	0.00170				0.05666		P	2.47736	2.66771	0.28329	1.24647	
B41							0.06106		0.17473	0.09498		0.00197		
42	P	0.42838										0.28887	7.92557	1.45987
A43		0.07609							10.66438			0.04791	2.57112	0.51856
44													P	
A45												1.05686		
A47	P									P		P		
49	0.01325	0.26435			0.01804		0.08004			0.07525				
A49	P				P		P			P				
51					0.41897		0.14114		0.27040	0.95384				
52					P		P			P				
53	P	0.00142					0.03006	P	P	0.12119				
A53	P	0.14264					0.06232		P	P		0.00376	0.25365	0.72336
54		0.04678			0.00620		0.18319		0.37448	0.18724				
55		0.02424		0.00423					P				0.82097	4.38976
56		0.06313		P	0.00845		0.23843		0.09753					
A56					0.43937		P			P				0.11752
C56		0.03861		0.00423			0.02536							0.22124
62			0.13528					0.56366		P				0.19728
A62		P			0.69104		0.06482			0.00367				
B62			0.00075				0.09019			0.04509		0.04509		
BLUFF	P	P								P				P
PHEL 1	P	0.07985					0.02114			0.49790		0.00057		
PHEL 4	0.53825	0.00850					0.00142					0.24801		
PHEL 7	0.01133	0.03088	0.50992	0.02914	0.01246	0.01671	0.02859		0.13738	0.50680	0.19830			
204		0.02691					0.07790			0.18414				
227	0.70822	0.01700	0.23230	0.00212	0.00496		0.05666		0.11332	0.10198	0.31728			
350			P			P		P		P				P
358														P
E 1**					0.22941		0.01691			P				
E 2**	0.14091				0.00564		0.01879		0.17755	0.09488				
NE 1**	P	P		P	0.48982				P	P				
NE 2**		P			0.29592				P	P				
NE 3**		P			0.13390					0.08369				
N 1**				P	1.75740					P				
N 2**					126.64443					P				
N 3**					12.66444				P	P				

P = present but no weights available; a blank space = not present

* See Fig. VI.D.1

**These stations do not appear on Fig. VI.D.1. They are east and north of Augustine Island, within 3 miles of the beach.

TABLE VI.D.VI

MEAN NUMBER OF PINK, HUMPY, COONSTRIPE AND SIDESTRIPE SHRIMPS CAPTURED IN TRAWLS IN COOK INLET, 1977 AND 1978

$\bar{x}$ = Mean, km = Kilometers, 0 = No specimens collected

Station Cook Inlet	Pink shrimp $\bar{x}$ per km fished	Humpy shrimp $\bar{x}$ per km fished	Coonstripe shrimp $\bar{x}$ per km fished	Sidestripe shrimp $\bar{x}$ per km fished
5	9	1	0	0
6	11	0	0	0
8	35	166	0	9
25	0	4	0	0
35	0	19	1	0
A36	0	10	0	0
37	926	171	176	15
38	65	301	41	0
A38	0	224	71	0
39	18	104	30	7
40	167	5	4	0
A40	0	0	10	0
41	1	0	0	0
49	0	36	0	0
A49	0	5	0	0
54	0	9	0	0
55	0	0	2	0
56	0	792	12	0
A56	0	125	0	0
C56	0	0	3	0
62	124	0	0	0
A62	0	275	0	0
B62	2	0	0	0
227	278	3	1	0
PMEL 7	202	24	19	5

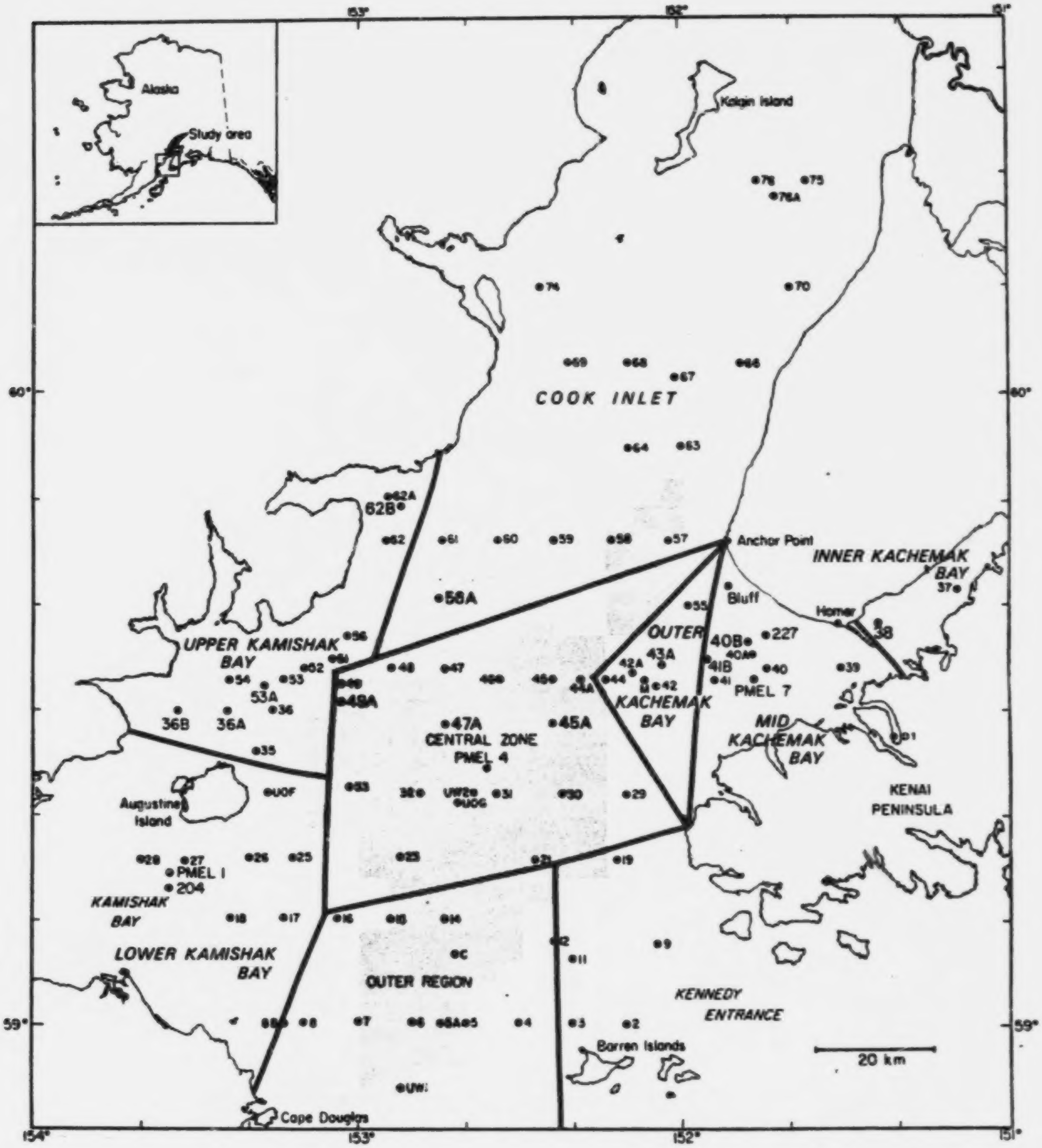

Alaska
Study area
Kalgin Island
COOK INLET
Anchor Point
INNER KACHEMAK BAY
Bluff
Homer
UPPER KAMISHAK BAY
OUTER KACHEMAK BAY
MID KACHEMAK BAY
CENTRAL ZONE
PMEL 4
PMEL 7
KENAI PENINSULA
Augustine Island
PMEL I
KAMISHAK BAY
LOWER KAMISHAK BAY
OUTER REGION
KENNEDY ENTRANCE
Barren Islands
Cape Douglas
20 km
153°
152°
151°
154°
60°
59°
76
75
76A
74
70
69
68
67
66
64
63
62A
62B
62
61
60
59
58
57
58A
56
55
40B
227
43A
42A
40A
41B
44A
44
42
41
40
39
37
38
54
53
53A
52
51
50
49A
48
47
46
45
36
36B
36A
35
47A
45A
33
32
UW2
UOG
31
30
29
UOF
28
27
204
26
25
23
21
19
18
17
16
15
14
12
11
9
C
8B
8
7
6
6A
5
4
3
2
UW
1

Figure VI.D.1. Lower Cook Inlet Benthic Stations and regions for grouping data for 1976, 1977 and 1978 (Feder *et al.*, 1980).

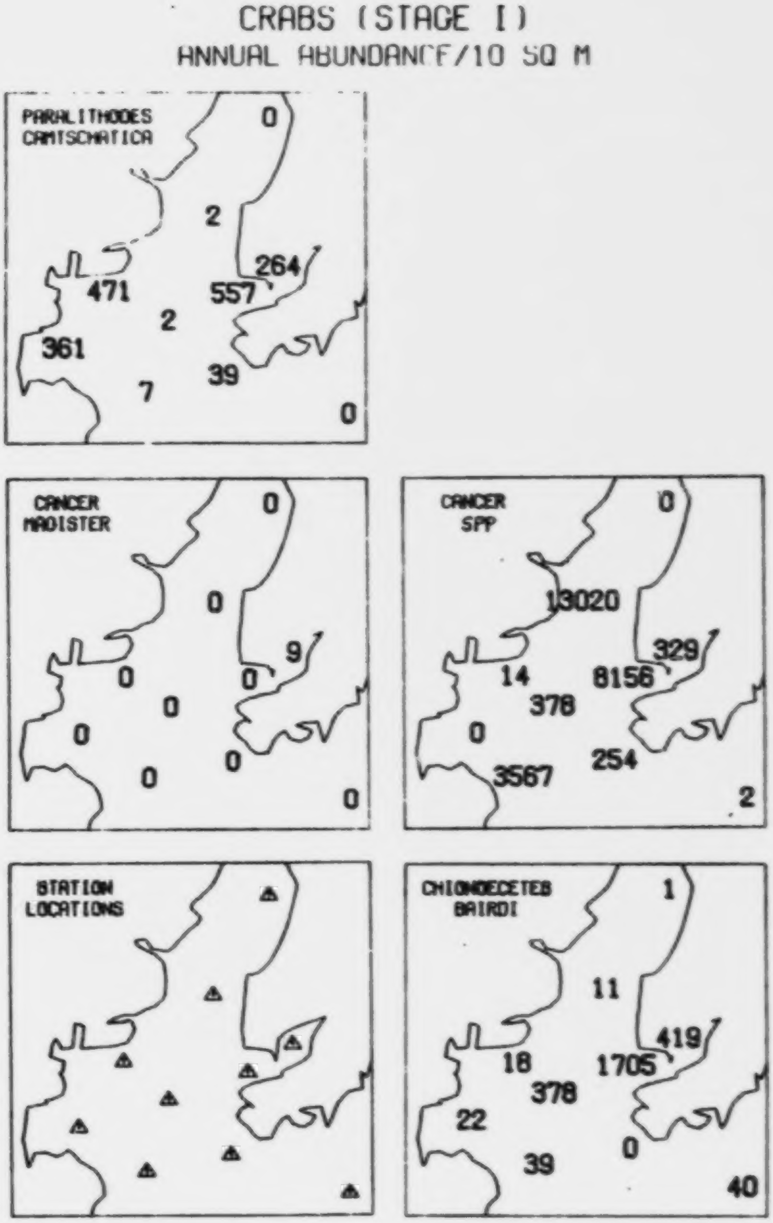

CRABS (STAGE I)
ANNUAL ABUNDANCE/10 SQ M
PARALITHODES CAMTSCHATICA
0
2
264
471
557
2
361
39
7
0
CANCER MAGISTER
0
0
9
0
0
0
0
0
0
0
CANCER SPP
0
13020
329
14
8156
378
0
254
3567
2
STATION LOCATIONS
CHIONOECETES BAIRDI
1
11
419
18
1705
378
22
0
39
40

Figure VI.D.2. Distribution of crab stage I zoeae (data from Dr. Tom English).

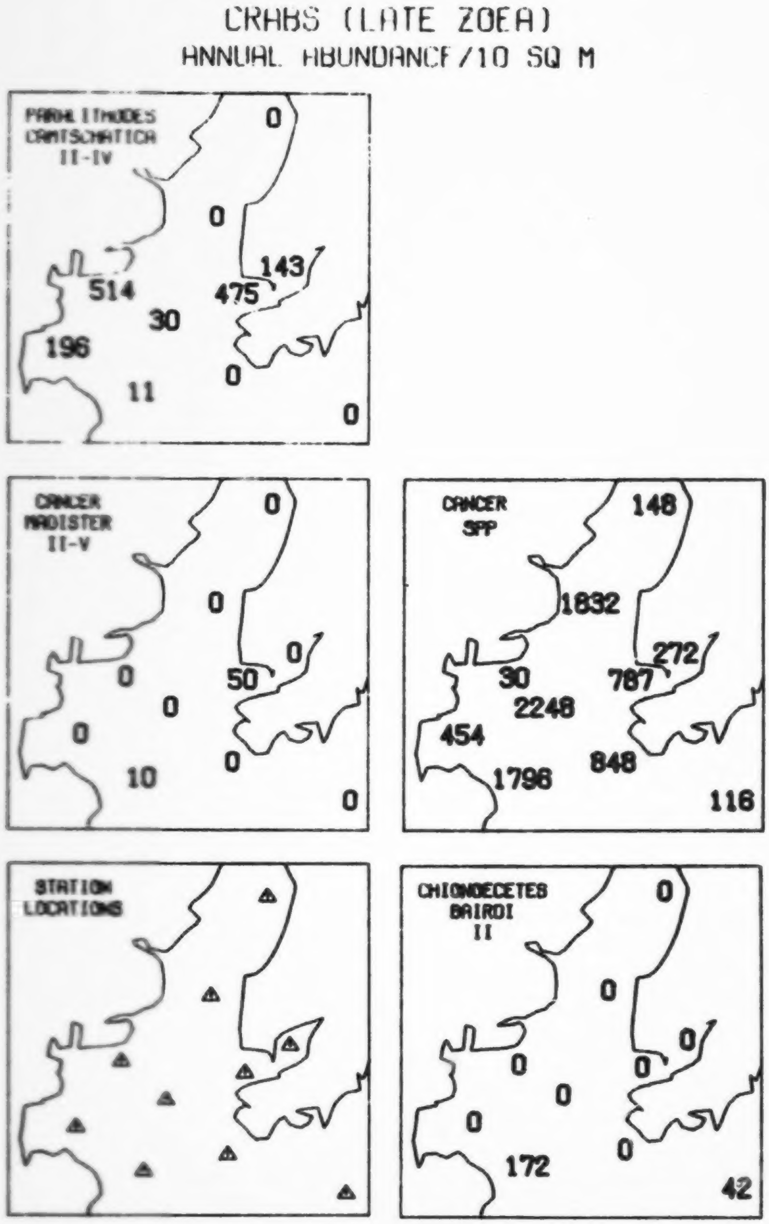

CRABS (LATE ZOEA)
ANNUAL ABUNDANCE/10 SQ M
PARALITHODES CAMTSCHATICA II-IV
0
0
143
514
475
30
196
0
11
0
CANCER MAGISTER II-V
0
0
0
0
50
0
0
0
10
0
CANCER SPP
148
1832
272
30
787
2248
454
848
1796
116
STATION LOCATIONS
CHIONOECETES BAIRDI II
0
0
0
0
0
0
0
172
0
42

Figure VI.D.3. Distribution of crab late zoeae (data from Dr. Tom English).

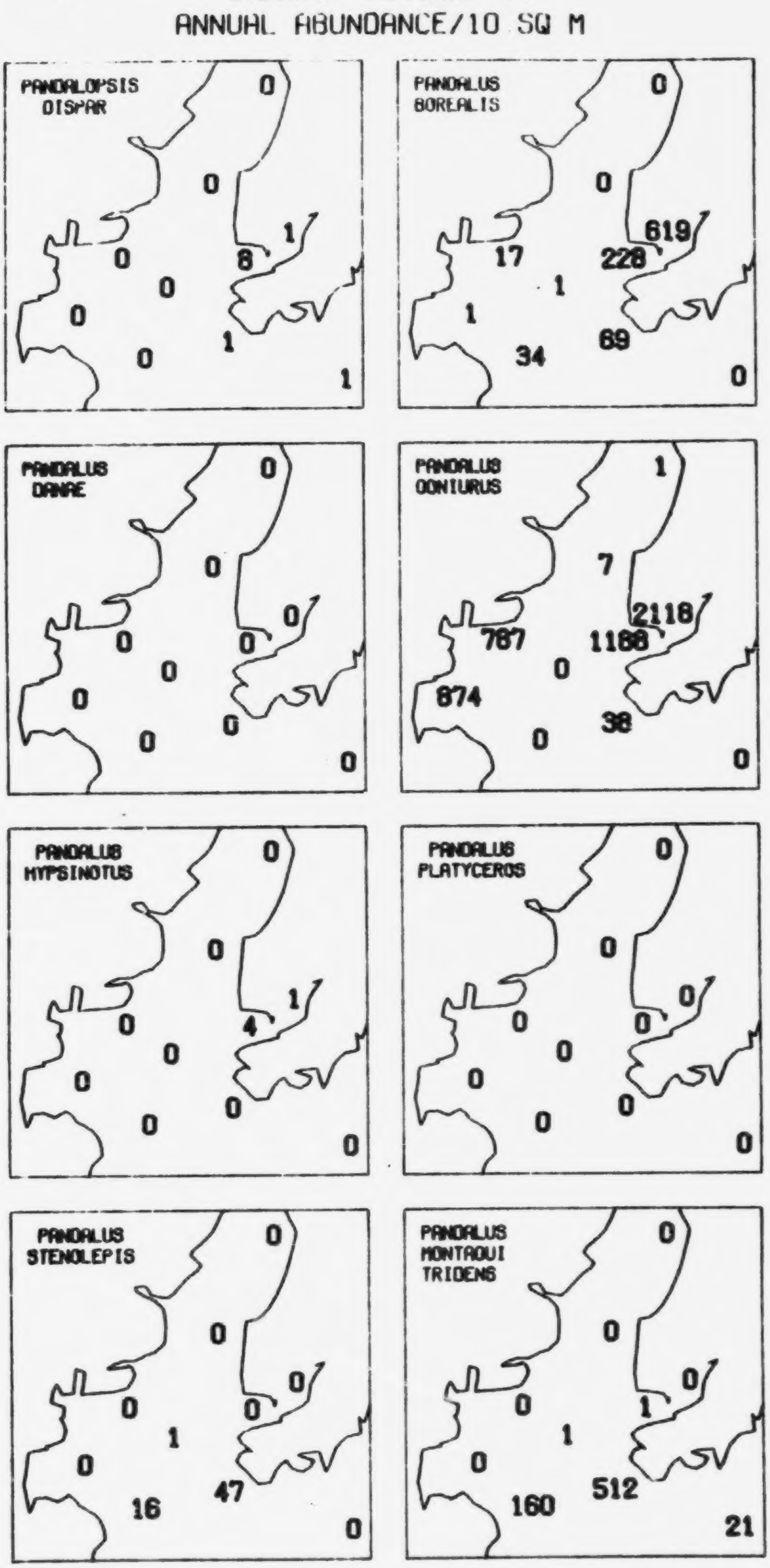

SHRIMP (STAGE I)
ANNUAL ABUNDANCE/10 SQ M
PANDALOPSIS DISPAR
0
0
1
0
8
0
0
1
0
1
PANDALUS BOREALIS
0
0
619
17
228
1
1
69
34
0
PANDALUS DANAE
0
0
0
0
0
0
0
0
0
0
PANDALUS GONIURUS
1
7
2118
787
1168
0
874
38
0
0
PANDALUS HYPSINOTUS
0
0
1
0
4
0
0
0
0
0
PANDALUS PLATYCEROS
0
0
0
0
0
0
0
0
0
0
PANDALUS STENOLEPIS
0
0
0
0
0
1
0
47
16
0
PANDALUS MONTAGUI TRIDENS
0
0
0
0
1
1
0
512
160
21

Figure VI.D.4. Distribution of shrimp stage I zoeae (data from Dr. Tom English).

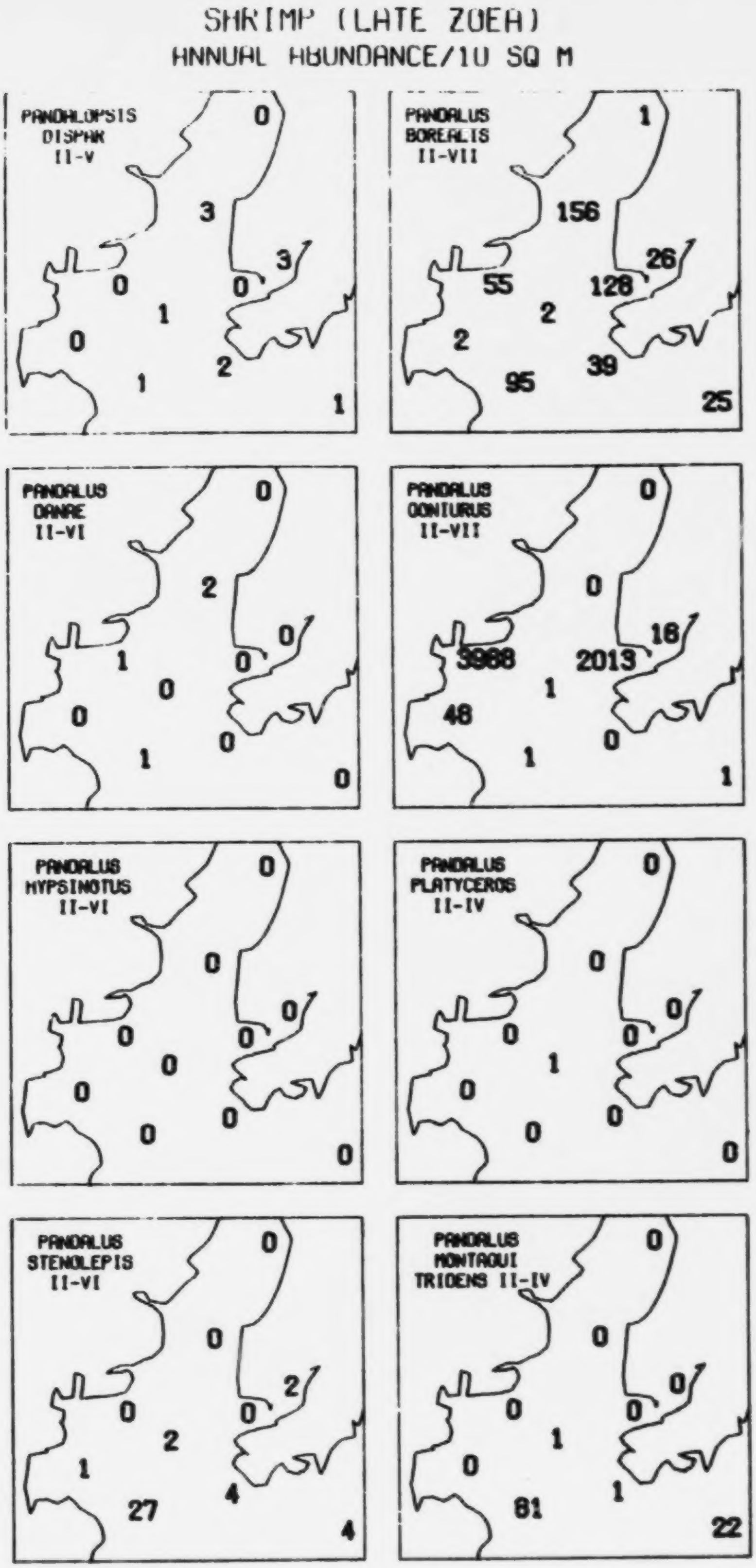

SHRIMP (LATE ZOEA)
ANNUAL ABUNDANCE/10 SQ M
PANDALOPSIS DISPAR II-V
0
3
3
0
0
1
0
2
1
1
PANDALUS BOREALIS II-VII
1
156
26
55
128
2
2
39
95
25
PANDALUS DANAE II-VI
0
2
0
1
0
0
0
0
1
0
PANDALUS GONIURUS II-VII
0
0
16
3988
2013
1
48
0
1
1
PANDALUS HYPSINOTUS II-VI
0
0
0
0
0
0
0
0
0
0
PANDALUS PLATYCEROS II-IV
0
0
0
0
0
1
0
0
0
0
PANDALUS STENOLEPIS II-VI
0
0
2
0
0
2
1
4
27
4
PANDALUS MONTAGUI TRIDENS II-IV
0
0
0
0
0
1
0
1
81
22

Figure VI.D.5. Distribution of shrimp late zoeae (data from Dr. Tom English).

SECTION E - CRITICAL PERIODS FOR BENTHIC INVERTEBRATES

The egg stages of brooding crustaceans may be sensitive to oil pollution; however, this remains to be documented. Pink shrimp, *Pandalus borealis*, generally carry their eggs from September to April. Snow crab, *Chionoecetes bairdi*, and king crab, *Paralithodes camtschatica*, carry eggs throughout the year (Al Davis, ADF&G Homer, pers. comm.). Thus, the critical period for the commercially important crustaceans may include all twelve months of the year, if their egg development is negatively effected by oil.

Survival rates of the larva of the commercially harvested crustaceans in Cook Inlet are negatively effected by the presence of crude oil at the parts per million concentrations (Rice *et al.*, 1976). Furthermore, if the behavior of Dungeness crab larvae are typical of other crab and shrimp species the zoeae cannot detect oil slicks and will swim into them (Rice *et al.*, 1976). The hatching periods for the commercially important crab and shrimp are outlined in Fig. VI.E.1. Hatching of snow and king crabs, pink and humpy shrimps occurs during April to August. The larvae of Dungeness crab are found in the water from May to December.

Crab and shrimp zoeae require crustacean prey concentrations on the order of 40 to 80 per liter to feed successfully (see Section B). If oil contamination negatively effected crustacean prey populations of the zoeae, then in addition to toxic effect of the oil, these zoeae would be subjected to the stress of starvation. Likewise, if crustacean prey concentrations were naturally low or dispersed throughout the water mass at densities less than 40 per liter by the mixing action of storms the zoeae could be in a starved condition and would be less likely to survive if further stressed by oil toxicity.

Water temperature effects the ability of king crab zoeae to capture prey when prey concentrations are low (see Section B). At temperatures of 2°C king crab zoeae that have failed to feed successfully during the first 2 to 3 days of life are less able to capture prey than zoeae in a similar state of nutrition held at 4° to 6°C. Therefore, the added stress of oil pollution would probably be more lethal to this species during the month of April, when temperatures on the order of 2°C may occur, than in later months when the water is warmer.

Snow crab, *Chionoecetes bairdi*, exposed to crude oil in the laboratory exhibit reductions in molting success and automotizing of limbs (Karinen and Rice, 1974). Therefore, oil pollution of the benthic environment could have a negative effect on snow crab survival if it occurred during a molting period. Adult females molt from April to July (A. Davis, ADF&G Homer, Alaska, pers. comm.). Newly settled snow crab may molt five times during the first year (Hilsinger, 1976) and, therefore, their molting period may include all 12 months of the year. The effect of crude oil on the molting success of the other crab and shrimp species of Cook Inlet is poorly understood.

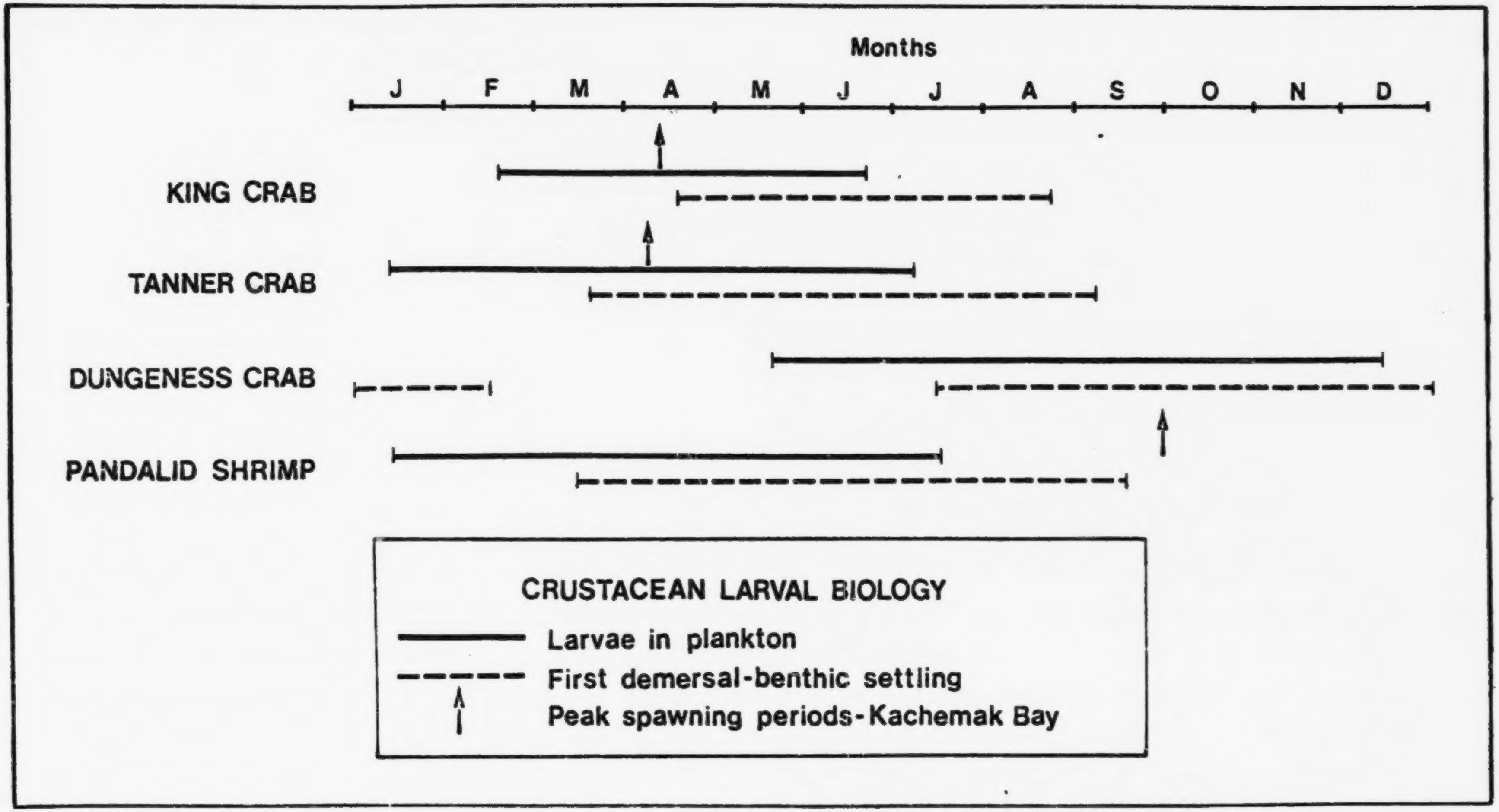


Figure VI.E.1. Larval periods for Cook Inlet crustaceans. Data from Alaska Department of Fish and Game (Figure taken from lower Cook Inlet Synthesis Report).

SECTION F - POTENTIAL FOR IMPACT FROM OCS OIL AND GAS EXPLORATION

Several organisms that are important in terms of numbers, weight, or economics occur at the benthic stations samples in Kachemak Bay, Kamishak Bay and near the mouth of the Inlet. Many of these species are somewhat migratory, and reside in an area for variable lengths of time. During the period in which they reside in an area one of their major activities is that of seeking food. Many of the taxonomic groups utilized as prey by the organisms that dominate in terms of number or weight must therefore recognized as "key prey species", whose abundance regulate the population size of their predators in an area. Community dominants have been suggested in Section A, and further discussion would be repetitious.

Drilling Rigs

Unless an oil spill results during drilling, the major hazard to the subtidal benthos from drilling will be exposure to drilling muds. The level of toxicity of drilling muds to subtidal benthos is undescribed.

Shore-based Facilities and Tanker Terminals

Potential new locations of shore-based facilities and tanker terminals include a possible support and supply facility at Homer, crude oil teminals and LNG plants in Kennedy Entrance, and at Anchor Point, and production treatment facilities in Kennedy Entrance, at Anchor Point and at Polly Creek, near Tuxedni Bay. No facilities are projected south of Tuxedni Bay, on the west side of Cook Inlet. Thus, impacts from these facilities on subtidal habitats would mainly occur in Kennedy Entrance, in Kachemak Bay, and near Anchor Point.

The main impacts would arise from acute or chronic oil contamination. Oil spills could occur at all facilities and from tanker accidents. Chronic contamination could occur at the production treatment facilities (disposal of production water) and at tanker terminals (disposal of ballast water and numerous minor spills).

The subtidal species assemblage in Kennedy Entrance is undescribed because the area was not trawlable. Therefore, a detailed discussion of potential impact of oil or gas related development is not possible. It seems probable that routine winter weather conditions would preclude safe, efficient tanker loading operations in the open waters of Kennedy Entrance, and thus would dictate that such facilities be located in its major embayments i.c., Port Chatham, Koyuktolik Bay, or Port Graham. The main concern to subtidal assemblages would be acute oil spills.

Consequences of either acute or chronic contamination at Anchor Point are of greater concern. Circulation studies indicate the presence of a gyre system in northwestern Kachemak Bay, over the northern shelf (Burbank, 1977). Residence time of the water mass in this system is not clear, but patterns of larval abundance suggest that it could act to concentrate contaminants. As pointed out in Section A and E, this area is part of the Kachemak Bay critical habitat for pandalid shrimp, king crab, Dungeness crab and snow crab. Potential effects of oil contamination have been discussed in Section E.

Pipelines

Pipelines are a potential concern because of the activities associated with laying the pipe and the possibility of breaks or small chronic leaks. Distribution of the oil would be dependent on the direction and strength of currents. Among the areas in which pipelines might effect subtidal habitats are in Kennedy Entrance and at Anchor Point.

A break in the pipeline would constitute an acute oil spill. The severity of the spill would depend upon the proximity of the break to the habitat and the amount of time required to stop the flow from the break. A pipeline break probably would be more damaging to the subtidal benthos than a surface spill because unweathered oil would be actively mixed into the water and with sediment. Because of the turbidity at Anchor Point and the proximity to the productive areas of Kachemak Bay, this is a special concern.

Other Concerns

Tanker routes and physical disturbance from boats or aircraft associated with petroleum exploration and development that do not result in pollution should have little effect on conditions on the subtidal organisms discussed in this report.

VII. REFERENCES

Abbott, R. T. 1974. American Seashells: The marine mollusca of the Atlantic and Pacific coasts of North America. 2nd Edition. Van Nostrand Reinhold Company, New York, N.Y. 663 pp.

Alaska Department of Fish and Game (ADF&G). 1976. A Fish and Wildlife Resource Inventory of the Cook Inlet-Kodiak Area. Under contract to Alaska Coastal Management Program, Division of Policy Development and Planning, Anchorage. 2 Vols., Vol. 2 - Fisheries. 434 pp.

Bigford, T. E. 1978. Effect of several diets on survival, development time, and growth of laboratory-reared spider crab, *Libinia emerginata*, larvae. *Fish. Bull.* 76(1):59-64.

Blumer, M. and J. Sass. 1972. Indigenous and petroleum-derived hydrocarbons in a polluted sediment. *Mar. Poll. Bull.* 3(6):92-93.

Blumer, M., G. Souza and J. Sass. 1971. Hydrocarbon pollution of edible shellfish by an oil spill. *Mar. Biol.* 5:195-202.

Brillouin, L. 1962. *Science and Information Theory*. Academy Press, New York. 169 pp.

Burbank, D. C. 1977. Circulation studies in Kachemak Bay and Lower Cook Inlet. *In* Environmental Studies of Kachemak Bay and lower Cook Inlet, Vol. III, Alaska Dept. Fish and Game, Anchorage, Alaska. 207 pp.

Butler, T. H. 1954. Food of the commercial crab in Queen Charlotte Islands region. Fish. Res. Bd. Can., Pacif. Prog. Rep. No. 99:3-5.

Clifford, H. T. and W. Stephenson. 1975. *An Introduction to Numerical Classification*. Academic Press. 22 pp.

Crow, J. H. 1977. Food habits of shrimp in Kachemak Bay, Alaska. L. L. Trasky, L. B. Flagg and D. C. Burbank (eds.), Environmental Studies of Kachemak Bay and Lower Cook Inlet, Alaska Dept. Fish and Game. 6:32 pp.

Damkaer, D. 1977. Initial zooplankton investigations in Prince William Sound, Gulf of Alaska and Lower Cook Inlet, 137-274. *In* Environmental Assessment of the Alaskan Continental Shelf: Annual Reports of Principal Investigators for the year ending March 1977. Vol. 10. Receptors-Fish, Littoral, Benthos. RU-425:586 pp.

Driskell, W. 1977. Benthic reconnaissance of Kachemak Bay, Alaska. *In* Environmental Studies of Kachemak Bay and Lower Cook Inlet. Vol. VII. 102 pp.

Ellertsen, B., E. Moksness, P. Solendal, T. Strømme, S. Tilseth, T. Westgard, and V. Øistad. 1977. Vertical distribution and feeding of cod larvae in relation to occurrence and size of prey organisms. Coun. Meet. Int. Coun. Explor. Sea (L:33), 32 pp.

English, T. S. 1979. Lower Cook Inlet meroplankton. OCSEAP Annual Report. 22 pp.

Evans, C. D., E. Buck, R. Buffler, G. Fisk, R. Forbes, and W. Parker. 1972. The Cook Inlet Environment. A Background Study of Available Knowledge. Alaska Sea Grant, Univ. Alaska, Anchorage.

Fager, F. W. 1972. Diversity: A sampling study. *Am. Nat.* 106:293-310.

Farrington, J. W. and J. G. Quinn. 1973. Petroleum hydrocarbons in Narragansett Bay. I. Survey of hydrocarbons in sediments and clams (*Mercenaria mercenaria*). *Est. Coast. Mar. Sci.* 1:71-79.

Feder, H. M. 1977. The distribution, abundance, diversity and biology of benthic organisms in the Gulf of Alaska and the Bering Sea. Annual Report to NOAA, R.U. #281/5/303. Inst. Mar. Sci., Univ. Alaska, Fairbanks. 340 pp.

Feder, H. M. and S. C. Jewett. 1977. The distribution, abundance, and diversity of the epifaunal benthic organisms in two bays (Alitak and Ugak) of Kodiak Island, Alaska. Final Report to NOAA, R.U. #29. Inst. Mar. Sci., Univ. Alaska, Fairbanks. 79 pp.

Feder, H. M., A. J. Paul and J. Paul. 1976. Growth and size-weight relationships of the pinkneck clam, *Spisula polynyma*, in Hartney Bay, Prince William Sound, Alaska. Proc. Natl. Shellfish. Assoc. 66:21-25.

Feder, H. M., M. Hoberg and S. C. Jewett. 1977. The distribution, (Alitak and Ugak) bays of Kodiak Island, Alaska. Annual Report to NOAA, R.U. #P29. Inst. Mar. Sci., Univ. Alaska, Fairbanks. p. 1-54.

Feder, H. M., K. Haflinger, M. Hoberg and J. McDonald. 1980. The infaunal invertebrates of the southeastern Bering Sea. Final Report to NOAA, R.U. #5. 399 pp.

Feder, H. M., S. Jewett, M. Hoberg, A. J. Paul, J. McDonald, G. Matheke and J. Rose. 1978. Distribution, abundance, community structure and trophic relationships of the near-shore benthos of the Kodiak shelf, Cook Inlet, northeast Gulf of Alaska and the Bering Sea. Annual Report to NOAA, R.U. #281/5/303. 315 pp.

Fenchel, T. M. and B. B. Jorgensen. 1977. Detritus food chains of aquatic ecosystems: the role of bacteria. *In* M. Alexander (ed.), Advances in Microbial Ecology, Vol. I.

Field, J. G. 1969. The use of the information statistic in the numerical classification of heterogenous systems. *J. Ecol.*. 57:565-569.

Field, J. G. 1970. The use of numerical methods to determine benthic distribution patterns from dredgings in False Bay. *Trans. Roy. Soc. S. Africa* 39:183-200.

Field, J. G. 1971. A numerical analysis of changes in the soft-bottom fauna along a transect across False Bay, South Africa. *J. Exp. Mar. Biol. Ecol.* 7:215-253.

Field, J. G. and G. MacFarlane. 1968. Numerical methods in marine ecology. I. A quantitative "similarity" analysis of rocky shore samples in False Bay, South Africa. *Zool. Africa* 3:119-137.

Fossato, V. U. and W. J. Canzonier. 1976. Hydrocarbon uptake and loss by the mussel *Mytilus edulis*. *Marine Biology* 36-243-250.

Gatto, L. W. 1976. Circulation and sediment distribution in Cook Inlet, Alaska. *In* Assessment of the Arctic Marine Environment; Selected Topics, 205-227. Inst. Mar. Sci., Univ. Alaska, Fairbanks.

Gotshall, D. W. 1977. Stomach contents of northern California Dungeness crabs, *Cancer magister*. Calif. Fish and Game 63(1):43-51.

Greenwood, J. G. 1972. The mouthparts and feeding behavior of two species of hermit crab. *J. Nat. Hist.* 6:325-337.

Gruffydd, LL. D. 1974. An estimate of natural mortality in an unfished population of the scallop *Pecten maximus* (L.). *J. Cons. Int. Explor. Mer* 35(2):209-210.

Haynes, E. 1977. Summary status on the distribution of king crab and pandalid shrimp larvae Kachemak Bay-Lower Cook Inlet, Alaska, 1976. *In* L. Trasky, L. Flagg and D. Burnbank (eds.), *Environmental Studies of Kachemak Bay and Lower Cook Inlet*. Alaska Dept. of Fish and Game, Anchorage, Alaska, Vol. 4. p. 1-52.

Hennick, D. 1973. Cook Inlet shellfish investigations, commercial fisheries research development act. Alaska Department of Fish and Game Project No. 5-29-R. Juneau, Alaska. 21 pp.

Hilsinger, J. R. 1976. Aspects of the reproductive biology of female snow crabs, *Chionoecetes bairdi*, from Prince William Sound and the adjacent Gulf of Alaska. *Mar. Sci. Commun.* 2(3,4):201-225.

Hurlbert, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. *Ecology* 52:577-586.

Hyman, L. M. 1940. The Invertebrates: Protozoa through Ctenophora. McGraw-Hill Co., New York. 726 pp.

Ishimaru, J. 1936. Data for forecasting catch of king crab in the Nemuro Area, Japan. Work Report Hokkaido Fisheries Experimental Station (Hokkaido Suisan Shikenjo Jigyo Jumpo), No. 332:294-295.

Jewett, S. C. and H. M. Feder. 1976. Distribution and abundance of some epibenthic invertebrates of the northeast Gulf of Alaska, with notes on the feeding biology of selected species. Inst. Mar. Sci. Tech. Rept. R76-8., Univ. Alaska, Fairbanks. 61 pp.

Karinen, J. F. and S. D. Rice. 1974. Effects of Prudhoe Bay crude oil on molting tanner crabs, *Chionoecetes bairdi*. MFR paper 1074.

Kinney, P. J., D. K. Button, D. M. Schell, B. R. Robertson and J. Graves. 1970. Quantitative assessment of oil pollution problems in Alaska's Cook Inlet. Inst. Mar. Sci., Univ. Alaska, Fairbanks. 116 pp.

Kon, T. 1971. Fisheries biology of the tanner crab-IV. The duration of planktonic stages estimated by rearing experiments of larvae. *Bull. Jap. Soc. of Sci. Fish.* 36(3):219-224. Fish. Res. Board of Canada Translation Series No. 1603.

Knull, J. and R. Williamson. 1969. Oceanographic survey of Kachemak Bay, Alaska. Bur. Comm. Fish. Biol. Lab., Auke Bay, Alaska, MR-F Nos. 60, 70 and 76.

Lance, G. N. and W. T. Williams. 1966. Computer programs for hierarchical polythetic classification ("similarity analyses"). *Comput. J.* 9:60-64.

Larrance, J. D. and A. J. Chester. 1979. Source, composition, and flux of organic detritus in lower Cook Inlet. OCSEAP Final Report. 50 pp.

Lasker, R. 1975. Field criteria for survival of anchovy larvae: the relation between inshore chlorophyll maximum layers and successful first feeding. *Fish. Bull.* 73(3):453-462.

Lasker, R. 1978. The relationship between oceanographic conditions and larval anchovy food in the California current: identification of factors contributing to recruitment failure. Rapp. P-v. Reun. Cons. Int. Explor. Mer. 173 pp.

Loya, Y. 1972. Community structure and species diversity of hermatypic corals at Eilat, Red Sea. *Mar. Biol.* 13:100-123.

Margalef. 1958. Information theory in ecology. *General Systems* 3:36-71.

Marukawa, H. 1933. Biological and fishery research on Japanese king crab, *Paralithodes camtschatica* (Tilesius). *J. Imperial Fish. Exp. Sta., Tokyo, No. U.* 152 pp.

Modin, J. C., and K. W. Cox. 1967. Post-embryonic development of laboratory-reared ocean shrimp, *Pandalus jordani* Rathbun. *Crustaceana* 13:197-219.

Moriarty, D. J. W. 1976. Quantitative studies on bacteria and algae in the food of the mullet *Mugil cephalus* and the prawn *Metapenaeus bennettae*. *J. Exp. Mar. Biol. Ecol.* 22:131-143.

Motoh, H. 1973. Laboratory-reared zoea and megalopae of Zuwai crab form the Sea of Japan. *Bull. Jap. Soc. of Sci. Fish.* 39(12):1223-1230.

Mueller-Dombois, D. and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. Wiley, New York. 547 pp.

Muench, R. D., H. D. Mofjeld and R. L. Charnell. 1978. Oceanographic conditions in lower Cook Inlet: spring and summer 1973. *J. Geophys. Res.* 83(C10):5090-5098.

Nakanishi, T. 1976. Rearing larvae and post-larvae of the king crab (*Paralithodes camtschatica*). FAO Technical Conference on Aquaculture at Kyoto, Japan, FIR:AQ/Conf/76/E:44. 7 pp.

Neiman, A. A. 1964. Age of bivalve molluscs and the utilization of benthos by flatfishes in the southeastern Bering Sea. *In* Soviet fisheries investigations in the northeast Pacific, Part 3. p. 191-196.

Nybakken, J. 1978. Abundance, diversity and temporal variability in a California intertidal nudibranch assemblage. *Mar. Biol.* 45:129-146.

Orton, J. H. 1927. On the mode of feeding of the hermit-crab, *Eupagurus bernhardus*, and some other Decapoda. *J. Mar. Biol. Assoc. U.K.* 14:909-921.

Paul, A. J. and H. M. Feder. 1973. Growth, recruitment and distribution of the littleneck clam, *Protothaca staminea*, in Galena Bay, Prince William Sound, Alaska. *Fish. Bull.* 71(3):665-677.

Paul, A. J., H. M. Feder and S. C. Jewett. 1979a. Food of the snow crab, *Chionoecetes bairdi* rathbun, 1924, from Cook Inlet, Alaska (Decapoda, Majidae). *Crustaceana, Suppl.* 5:62-68.

Paul, A. J., J. M. Paul, P. A. Shoemaker and H. M. Feder. 1979b. Prey concentration and feeding response in laboratory-reared stage one zoeae of king crab, snow crab, and pink shrimp. *Trans. Am. Fish. Soc.* 108:440-443.

Paul, A. J. and J. M. Paul. In press. The effect of early starvation on later feeding success of king crab zoeae. *J. Exp. Mar. Biol. Ecol.*

Pearson, T. H. 1972. The effect of industrial effluent from pulp and paper mills on the marine benthic environment. *Proc. Roy. Soc. Lond. B.* 130:469-485.

Pearson, T. H. 1975. The benthic ecology of Loch Linnke and Loch Eil, a sea loch system on the west coast of Scotland. IV. Changes in the benthic fauna attributable to organic enrichment. *J. Exp. Mar. Biol. Ecol.* 20:1-41.

Pearson, T. H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanogr. Mar. Biol. Ann. Rev.* 16:229-311.

Peet, R. K. 1974. The measurement of species diversity. *A. Rev. Ecol. Syst.* 5:285-307.

Pielou, E. C. 1966a. Species-diversity and pattern-diversity in the study of ecological succession. *J. Theor. Biol.* 10:370-383.

Pielou, E. C. 1966b. The measurement of diversity in different types of biological collections. *J. Theor. Biol.* 13:131-144.

Pielou, E. C. 1977. *Mathematical Ecology.* Wiley, New York. 285 pp.

Rhoads, D. C. 1974. Organism-sediment relations on the muddy sea floor. *Oceanogr. Mar. Biol. Ann. Rev.* 12:263-300.

Rice, S., J. Short, C. Brodensen, T. Mecklenburg, D. Moles, C. Misch, D. Cheatham and J. Karinen. 1976. Acute Toxicity and Uptake-Depuration Studies with Cook Inlet Crude Oil, Prudhoe Bay Crude Oil, No. 2 Fuel Oil and Several Subarctic Marine Organisms. Northwest Fisheries Center. Auke Bay, Alaska. 87 pp.

Rieper, M. 1978. Bacteria as food for marine harpacticoid copepods. *Mar. Biol.* 45:337-345.

Sager. P. and A. C. Hasler. 1969. Species diversity in lacustrine phytoplankton. I. The components of the index of diversity from Shannon's formula. *Am. Nat.* 102:243-282.

Satoe, S. 1958. Studies on larval development and fishery biology of king crab, *Paralithodes camtschatica* (Tilesius). *Bull. Hokkaido Reg. Fish. Res. Lab.*, No. 17. 103 pp.

Scarratt, D. J. and V. Zitko. 1972. Bunker C oil in sediments and benthic animals from shallow depths in Chedabucto Bay, N.S. *J. Fish. Res. Bd. Can.* 29:1347-1350.

Shannon, C. E. and W. Weaver. 1963. *The Mathematical Theory of Communication.* Univ. Illinois Press, Urbana. 117 pp.

Shaw, D. G., A. J. Paul, L. M. Cheek and H. M. Feder. 1976. *Macoma balthica*: an indicator of oil pollution. *Mar. Pull. Bull.* 7:29-31.

Smith, J. E. (ed.). 1968. *Torrey Canyon Pollution and Marine Life.* Cambridge Univ. Press, Cambridge. 196 pp.

Snedecor, G. W. 1956. *Statistical methods applied to experiments in agriculture and biology.* 5th ed. Iowa State Coll. Press, Ames. 534 pp.

Stephenson, W. and W. T. Williams. 1971. A study of the benthos of soft bottoms. Sek Harbour, New Guinea, using numerical analysis. *Aust. J. Mar. Freshwater Res.* 22:11-34.

Stephenson, W., W. T. Williams and S. Cook. 1972. Computer analyses of Petersen's original data on bottom communities. *Ecol. Monogr.* 42:387-415.

Straughan, D. 1971. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Allan Hancock Foundation, Univ. Southern California, Los Angeles. 425 pp.

Sundberg, K. A. and D. Clausen. 1977. Post-larval king crab (*Paralithodes camtschatica*) distribution and abundance in Kachemak Bay, lower Cook Inlet, Alaska, 1976. *In* L. Trasky, L. Flagg and D. Burbank (eds.), Environmental Studies of Kachemak Bay and Lower Cook Inlet, Alaska Dept. Fish and Game. 5:36 pp.

Takeuchi, I. 1968a. Food of the king crab, *Paralithodes camtschatica*, off the west coast of Kamchatka in 1958. Fish. Res. Bd. Can. Transl. Ser. No. 1193:21 pp. From *Bull. Hokkaido Reg. Fish. Res. Lab* 33:23-44, 1959.

Takeuchi, I. 1968b. Food of the king crab, *Paralithodes camtschatica*, off the west coast of the Kamchatka Penninsula, 1958-1964. Fish Res. Bd. Can. Transl. Ser. No. 1194:21 pp. From *Bull. Jap. Sea Reg. Fish. Res. Lab.* 33:32-44, 1967.

Tarverdieva, M. I. 1976. Feeding of the Kamchatka king crab, *Paralithodes camtschatica*, and tanner, crabs, *Chionoecetes bairdi* and *Chionoecetes opilio*, in the southern part of the Bering Sea. *Soviet. J. Mar. Biol.* 2(1):34-39.

U. S. Bureau of Commercial Fisheries, USF&WS: Exploratory Trawl Survey Data. 1958, 1961, 1963. Supplied by U.S. Department of Commerce, NMFS, Northwest Fisheries Center, Seattle, Washington.

U. S. Department of Commerce. 1970. Surface water temperature and density: Pacific coast North and South American and Pacific Ocean Islands. Nat. Ocean Survey Publication 31-3. 88 pp.

U. S. Department of Interior. 1977. Lower Cook Inlet Final Environmental Impact Statements. Alaska Outer Continental Shelf Office. Vol. 1. 561 pp.

Weymouth, F. W. 1923. The life history and growth of the pismo clam, *Tivela stultorum* (Mawe). *Calif. Fish and Game Comm. Fish. Bull.* 7:120 pp.

Yasuda, T. 1967. Feeding habit of the zawai-gani, *Chionoecetes opilio elongatus*, in Wakasa Bay. I. Specific composition of the stomach contents. *Bull. Jap. Soc. Sci. Fish.* 33(4):315-319. (Transl. from Japanese by Fish. Res. Bd. Can., Transl. Ser. No. 1111.)

APPENDIX I

INVERTEBRATE TAXA OBTAINED BY AGASSIZ TRAWL, TRY-NET TRAWL AND EASTERN OTTER TRAWL IN LOWER COOK INLET

APPENDIX I - TABLE I

INVERTEBRATE TAXA OBTAINED BY AGASSIZ TRAWL, TRY-NET TRAWL AND EASTERN OTTER TRAWL IN LOWER COOK INLET

Taxon	Agassiz Trawl		Try-Net	Eastern Otter Trawl
	Apr	Oct	Apr	Oct
Phylum Porifera				
Unidentified species	x	-	x	x
Phylum Cnidaria				
Class Hydrozoa				
Unidentified species	x	-	x	x
Family Campanulariidae				
Campanularia sp.	-	-	-	-
Family Sertulariidae				
Unidentified species	-	-	-	-
Sertularia sp.	-	-	-	-
Sertularella sp.	-	-	-	-
Abietinaria sp.	-	-	-	-
Family Plumulariidae				
Unidentified species	-	-	-	-
Family Stylasteridae				
Allopora sp.	-	-	-	-
Class Anthozoa				
Family Nephtheidae				
Eunephthya rubiformis	x	-	-	-
Family Primnoidae				
Stylatula gracile	x	-	-	-
Family Pennatulidae				
Ptilosarcus gurneyi	x	-	-	x
Family Actiniidae				
Unidentified species	x	x	-	x
Tealia crassicornis	x	-	-	x
Phylum Platyhelmintes				
Class Turbellaria				
Order Polycladia				
Unidentified species	-	-	-	-
Phylum Annelida				
Class Polychaeta				
Unidentified species	x	x	-	x
Family Aphroditidae				
Aphrodita japonica	-	x	-	-

APPENDIX I - TABLE I

CONTINUED

Taxon	Agassiz Trawl		Try-Net	Eastern Otter Trawl
	Apr	Oct	Apr	Oct
Phylum Annelida (cont'd)				
Family Polynoidae				
Unidentified species	x	x	x	x
Family Nereidae				
Nereis sp.	-	x	-	x
Class Hirudinea				
Family Piscicolidae				
Notostomobdella sp.	x	x	-	-
Phylum Mollusca				
Class Polyplacophora				
Family Ischnochitonidae				
Ischnochiton trifidus	-	-	-	-
Class Pelecypoda				
Unidentified species	-	x	-	-
Family Nuculidae				
Nucula tenuis	-	x	-	-
Family Nuculanidae				
Nuculana fossa	-	x	x	-
Yoldia thraciaeformis	-	x	-	-
Family Glycymerididae				
Glycymeris subobsoleta	-	-	x	-
Family Mytilidae				
Mytilis edulis	-	-	-	-
Modiolus modiolus	x	-	x	-
Family Pectinidae				
Chlamys rubida	x	x	-	x
Pecten caurinus	-	-	x	-
Propeamussium davidsoni	-	x	-	-
Family Astartidae				
Astarte alaskensis	x	-	-	-
Astarte rollandi	x	-	-	-
Family Carditidae				
Cyclocardia sp.	-	-	x	-
Cyclocardia ventricosa	x	-	-	-
Cyclocardia crassidens	x	-	-	-
Family Cardiidae				
Clinocardium sp.	-	-	x	-
Clinocardium ciliatum	x	-	-	-
Clinocardium nuttallii	x	-	-	-
Clinocardium californiense	x	-	-	-
Serripes groenlandicus	x	x	x	x

APPENDIX I - TABLE I

CONTINUED

	Agassiz Trawl		Try-Net	Eastern Otter Trawl
Taxon	Apr	Oct	Apr	Oct
Phylum Mollusca (cont'd)				
Family Veneridae				
Humilaria kennerlyi	-	-	-	-
Protothaca staminea	-	-	-	-
Family Mactridae				
Spisula polynyma	x	-	-	-
Family Tellinidae				
Macoma sp.	-	-	x	-
Macoma calcarea	x	-	x	-
Tellina nuculoides	-	-	x	-
Family Hiatellidae				
Hiatella arctica	x	-	-	x
Class Gastropoda				
Family Trochidae				
Bathybembix sp.	x	-	-	-
Margarites olivaceus	-	-	-	-
Margarites costalis	-	x	-	-
Solariella varicosa	-	x	-	-
Lischkeia cidaris	-	x	-	-
Family Epitoniidae				
Epitonium groenlandicum	x	-	-	-
Family Eulimidae				
Balcis sp.	x	-	-	-
Family Calyptraeidae				
Crepidula nummaria	x	-	-	-
Family Naticidae				
Natica clausa	x	-	-	-
Polinices pallida	x	-	x	-
Family Cymatiidae				
Fusitriton oregonensis	x	-	x	x
Family Muricidae				
Boreotrophon clathratus	x	-	-	-
Boreotrophon stuarti	x	-	-	-
Boreotrophon pacificus	x	-	-	-
Boreotrophon lasius	x	-	-	-
Boreotrophon multicostalis	x	-	-	-
Family Thaididae				
Nucella lamellosa	x	-	x	x
Family Buccinidae				
Buccinum cnismatum	-	x	-	-
Buccinum glaciale	x	-	-	-
Buccinum plectrum	x	-	x	-

APPENDIX I - TABLE I

CONTINUED

Taxon	Agassiz Trawl		Try-Net	Eastern Otter Trawl
	Apr	Oct	Apr	Oct
Phylum Mollusca (cont'd)				
Family Neptuneidae				
Beringius kennicotti	x	-	-	x
Colus sp.	-	x	-	-
Colus halli	x	-	-	-
Colus herendeenii	x	-	-	-
Neptunea lyrata	x	x	x	x
Neptunea ventricosa	-	-	-	-
Plicifusus kroyeri	x	-	-	-
Pyrulofusus harpa	x	-	-	-
Volutopsius middendorfii	x	-	-	-
Family Volutomitridae				
Volutomitra alaskana	x	-	-	-
Family Cancellariidae				
Admete couthouyi	x	-	-	-
Family Turridae				
Suavodrillia kennicottii	-	x	-	-
Oenopota decussata	-	x	-	-
Propebela sp.	-	x	-	-
Family Dorididae				
Unidentified species	-	x	-	x
Family Dendronotidae				
Unidentified species	-	x	-	-
Family Tritoniidae				
Tritonia exsulans	x	-	-	-
Phylum Arthropoda				
Class Pycnogonida				
Unidentified species	-	x	-	-
Class Crustacea				
Order Thoracica				
Family Balanidae				
Balanus sp.	x	x	-	x
Balanus balanus	-	-	-	x
Balanus evermani	x	-	-	-
Balanus hesperius	x	x	-	x
Balanus hoekianus	x	-	-	-
Balanus rostratus	-	-	x	x
Order Mysidacea				
Unidentified species	-	x	-	-
Family Mysidae				
Acanthomysis dybowskii	-	x	-	-

APPENDIX I - TABLE I

CONTINUED

Taxon	Agassiz Trawl		Try-Net	Eastern Otter Trawl
	Apr	Oct	Apr	Oct
Phylum Arthropoda (cont'd)				
Order Cumacea				
Family Diastylidae				
Diastylis bidentata	-	x	-	-
Order Isopoda				
Family Aegidae				
Rocinela augustata	-	x	-	-
Order Amphipoda				
Unidentified species	x	x	-	-
Family Ampeliscidae				
Ampelisca macrocephala	x	-	-	-
Ampeliscida birulai	x	x	-	-
Byblis gaimandi	x	-	-	-
Family Corophiidae				
Ericthonius sp.	x	-	-	-
Ericthonius folli	-	x	-	-
Family Lysianassidae				
Anonyx sp.	-	x	-	-
Anonyx nugax	-	x	-	-
Lepidepecreum comatum	-	x	-	-
Family Oedicerotidae				
Monoculodes zernovi	-	x	-	-
Family Phoxocephalidae				
Heterophoxus oculatus	x	-	-	-
Family Caprellidae				
Unidentified species	x	x	-	-
Order Decapoda				
Family Pandalidae				
Pandalus sp.	-	-	x	-
Pandalus borealis	x	x	x	x
Pandalus goniurus	x	x	x	x
Pandalus hypsinotus	x	x	x	x
Pandalopsis dispar	x	x	-	-
Family Hippolytidae				
Spirontocaris lamellicornis	x	x	-	-
Lebbeus groenlandica	x	-	x	x
Eualus sp.	x	-	-	-
Eualus suckleyi	-	x	-	-
Eualus townsendi	x	-	x	-
Family Crangonidae				
Crangon sp.	x	-	-	-
Crangon communis	x	x	x	-

APPENDIX I - TABLE I

CONTINUED

Taxon	Agassiz Trawl		Try-Net	Eastern Otter Trawl
	Apr	Oct	Apr	Oct
Phylum Arthropoda				
Family Crangonidae (cont'd)				
Crangon resina	-	x	-	-
Crangon dalli	x	x	x	x
Sclerocrangon boreas	-	-	x	-
Argis dentata	x	x	x	x
Argis crassa	x	-	x	x
Family Paguridae				
Pagurus sp.	x	-	-	-
Pagurus ochotensis	x	x	x	x
Pagurus aleuticus	x	x	x	x
Pagurus capillatus	x	x	x	x
Pagurus kennerlyi	x	x	x	x
Pagurus beringanus	x	-	-	x
Pagurus confragosus	x	-	-	-
Pagurus trigonocheirus	x	-	-	-
Elassochirus tenuimanus	x	x	x	x
Elassochirus cavimanus	-	-	-	x
Elassochirus gilli	x	-	-	-
Labidochirus splendescens	x	-	x	-
Family Lithodidae				
Paralithodes camtschatica	x	x	x	x
Rhinolithodes wosnessenskii	x	-	-	-
Family Majidae				
Oregonia gracilis	x	x	x	x
Hyas lyratus	x	x	x	x
Chionoecetes bairdi	x	x	x	x
Chorilia longipes	-	-	x	-
Family Cancridae				
Cancer oregonensis	x	-	x	x
Cancer magister	x	-	-	x
Family Pinnotheridae				
Pinnixa occidentalis	x	-	-	-
Phylum Ectoprocta				
Unidentified species	x	-	x	x
Class Cheilostomata				
Family Membraniporidae				
Membranipora sp.	x	-	-	-
Family Flustridae				
Unidentified species	-	-	-	-

APPENDIX I - TABLE I

CONTINUED

Taxon	Agassiz Trawl Apr	Agassiz Trawl Oct	Try-Net Apr	Eastern Otter Trawl Oct
Phylum Ectoprocta (cont'd)				
Family Microporidae				
Microporina sp.	-	-	-	-
Class Cyclostomata				
Family Heteroporidae				
Heteropora sp.	x	-	-	-
Class Ctenostomata				
Family Alcyonidiidae				
Alcyonidium sp.	-	-	-	x
Family Flustrellidae				
Flustrella sp.	x	-	-	x
Flustrella gigantea	-	-	-	-
Phylum Brachiopoda				
Family Dallinidae				
Laqueus californianus	x	-	-	-
Terebratalia transversa	x	-	-	x
Phylum Echinodermata				
Class Asteroidea				
Family Goniasteridae				
Ceramaster patagonicus	x	-	-	x
Ceramaster stellatus	-	x	-	-
Family Porcellanasteridae				
Ctenodiscus crispatus	x	x	-	-
Family Echinasteridae				
Henricia sp.	x	x	x	-
Henricia leviuscula	-	-	-	-
Family Pterasteridae				
Pteraster tesselatus	x	-	-	x
Family Asteridae				
Evasterias troschelii	x	-	-	x
Leptasterias sp.	x	-	-	-
Leptasterias polaris	x	-	-	x
Lethasterias sp.	-	-	-	x
Lethasterias nanimensis	x	-	-	x
Family Solasteridae				
Crossaster papposus	x	-	-	x
Crossaster borealis	x	-	-	-
Solaster dawsoni	x	-	-	-

APPENDIX I -TABLE I

CONTINUED

	Agassiz Trawl		Try-Net	Eastern Otter Trawl
Taxon	Apr	Oct	Apr	Oct
Phylum Echinodermata (cont'd)				
Class Echinoidea				
Family Echinarachniidae				
Echinarachnius parma	x	-	-	-
Family Strongylocentrotidae				
Strongylocentrotus droebachiensis	x	x	-	x
Strongylocentrotus franciscanus	-	-	-	x
Class Ophiuroidea				
Family Gorgonocephalidae				
Gorgonocephalus caryi	x	-	-	-
Family Amphiuridae				
Amphipholis pugetana	-	x	-	-
Family Ophiactidae				
Ophiopholis aculeata	x	-	-	-
Family Ophiuridae				
Ophiopenia disacantha	-	x	-	-
Ophiopenia tetracantha	-	x	-	-
Ophiura sarsi	x	x	-	-
Class Holothuroidea				
Family Synaptidae				
Unidentified species	-	x	-	-
Family Cucumariidae				
Cucumaria sp.	x	x	-	-
Cucumaria calcigera	-	-	-	-
Phylum Chordata				
Subphylum Urochordata				
Unidentified species	x	-	x	-
Family Styelidae				
Unidentified species	-	x	-	-
NUMBER OF SPECIES	149		45	53

APPENDIX II

TAXA FROM BOTTOM SKIMMER STATIONS, 10 AUGUST 1976

APPENDIX II - TABLE I

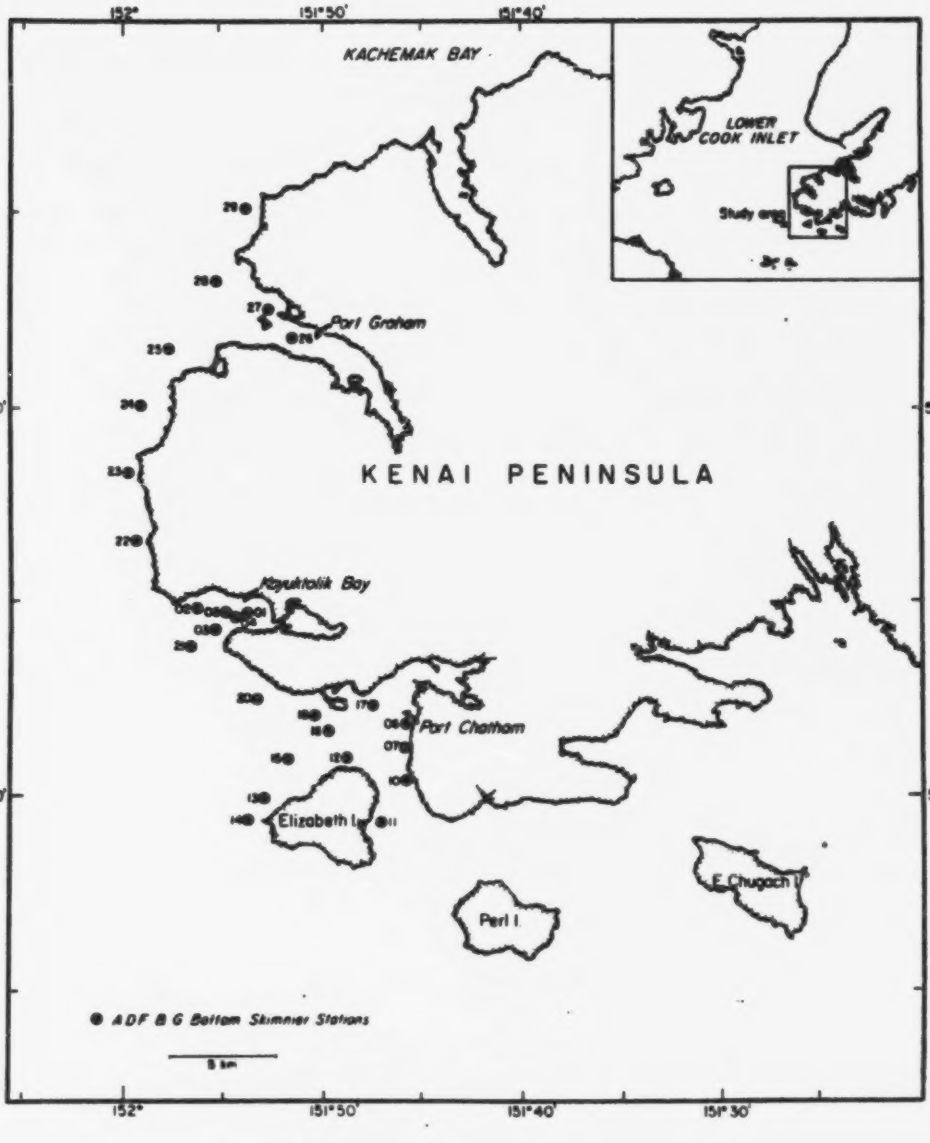
TAXA FROM BOTTOM SKIMMER STATION 01, 18.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Cnidaria	
Hydrozoa	F
Annelida	
Serpulidae	A
Polynoidae	C
Nereidae	N
Mollusca	
Tellina nuculoides	C
Clycymeris subobsoleta	C
Hiatella arctica	C
Cyclocardia crebricostata	I
Musculus vernicosus	F
Olivella baetica	F
Psephidia lordi	C
Arthropoda	
Balanus sp.	F
Cumacea	A
Caprellidea	A
Gammaridae (6 species)	A
Pagurus sp.	F
Elassochirus tenuimanus	C
Elassochirus gilli	I
Sclerocrangon boreas	F
Crangon sp.	C
Telmessus cheiragonus	I
Hyas lyratus	I
Oregonia gracilis	I
Ectoprocta	
Echinodermata	
Ophiuroidea	C
Urochorda	
Solitary ascidian	F
Compound ascidian	I

Comments: Lots of kelp and pieces of wood

[1] Relative Abundance: I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)



152°
151°50'
151°40'
151°30'
59° 20'
59° 10'
KACHEMAK BAY
LOWER COOK INLET
Study area
Port Graham
KENAI PENINSULA
Kayuktolik Bay
Port Chatham
Elizabeth I.
Perl I.
E. Chugach I.
29
28
27
26
25
24
23
22
02
05
01
03
21
20
19
18
17
08
07
16
12
10
13
14
11
ADF & G Bottom Skimmer Stations
5 km

Appendix II-Figure 1. Bottom skimmer stations occupied by Alaska Department of Fish and Game, August 1976.

BEST DOCUMENT AVAILABLE

APPENDIX II - TABLE II

TAXA FROM BOTTOM SKIMMER STATION 02, 20.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	I
Annelida	
Syllidae	I
Polynoidae	I
Mollusca	
Modiolus modiolus	I
Musculus discors	I
Cyclocardia crebricostata	I
Crenella decussata	C
Hiatella arctica	I
Tellina nuculoides	I
Glycymeris subobsoleta	A
Astarte rollandi	C
Limatula subauriculata	I
Olivella baetica	F
Polynices pallida	I
Fusitriton oregonensis	I
Velutina sp.	I
Lacuna sp.	I
Crepidula nummaria	I
Ischnochiton sp.	I
Arthropoda	
Balanus sp.	I
Pentidotea sp.	I
Gammaridae (6 species)	F
Cumacea	I
Hyppolytidae	I
Crangon dalli	I
Argis crassa	I
Pagurus ochotensis	I
Pagurus capillatus	I
Pagurus beringanus	I
Elassochirus tenuimanus	F
Hyas lyratus	F
Oregonia gracilis	F
Ectoprocta	
Alcyonidium sp.	I
Flustra sp.	I
Microporina sp.	I

APPENDIX II - TABLE II

CONTINUED

Taxon	Relative Abundance[1]
Brachiopoda	
Terebratalia transversa	I
Echinodermata	
Ophiuroidea	I
Brisaster townsendi	I
Strongylocentrotus droebachiensis	I
Urochorda	
Compound ascidian	F

Comments: Numerous green, brown and red algal fragments.

[1] Relative Abundance: I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE III

TAXA FROM BOTTOM SKIMMER STATION 03, 25.6 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	I
Mollusca	
Astarte rollandi	I
Glycymeris subobsoleta	I
Musculus discors	I
Olivella baetica	I
Arthropoda	
Balanus sp.	F
Pandalus sp.	F
Pandalus borealis	I
Argis crassa	I
Crangon dalli	I
Sclerocrangon boreas	I
Eualus sp.	I
Pagurus kennerlyi	I
Elassochirus tenuimanus	C
Elassochirus gilli	I
Echinodermata	
Lophaster sp.	I

Comments: Large fragments of brown and red algae.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE IV

TAXA FROM BOTTOM SKIMMER STATION 04, 18.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	I
Cnidaria	
Hydrozoa	I
Annelida	
Serpulidae	I
Mollusca	
Humilaria kennerlyi	I
Olivella baetica	I
Arthropoda	
Mysidacea	I
Crangon dalli	I
Sclerocrangon boreas	I
Eualus sp.	I
Heptacarpus tridens	I
Pagurus sp.	I
Pagurus trigonochirus	I
Pagurus beringanus	I
Elassochirus tenuimanus	I
Cancer oregonensis	I
Oregonia gracilis	I
Ectoprocta	
Flustrella gigantea	I
Echinodermata	
Strongylocentrotus droebachiensis	I

Comments: Sea grass and brown algae present.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE V

TAXA FROM BOTTOM SKIMMER STATION 05, 20.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Annelida	
Glyceridae	I
Ampharetidae	I
Nephtyidae	F
Nereidae	I
Serpulidae	C
Terebellidae	F
Phyllodocidae	F
Mollusca	
Astarte sp.	F
Glycymeris subobsoleta	I
Cyclocardia crebricostata	I
Musculus discors	C
Olivella baetica	F
Cylichna sp.	I
Arthropoda	
Mysidacea	A
Crangon dalli	C
Argis sp.	I
Sclerocrangon boreas	I
Elassochirus tenuimanus	I
Pagurus sp.	I
Spirontocaris sp.	F
Caprellidea	I
Gammaridea (4 species)	N
Lebbeus groenlandicus	I
Ectoprocta	
Echinodermata	
Strongylocentrotus droebachiensis	I

Comments: Substrate - coarse sand; lots of algae and seaweeds.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

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APPENDIX II - TABLE VI

TAXA FROM BOTTOM SKIMMER STATION 06, 9.1-18.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	I
Cnidaria	
Hydrozoa	I
Annelida	
Sabellidae (small)	A
Polynoidae	C
Cistenides sp. (small)	C
Mollusca	
Pododesmus macrochisma	C
Natica sp.	F
Olivella baetica	I
Fusitriton oregonensis	I
Nassarius sp.	F
Trichotropis sp.	I
Calliostoma sp.	I
Nudibranch	I
Mya truncata (dead)	I
Tellina nuculoides (small)	I
Arthropoda	
Isopoda (one Ectoparasitic form)	I
Amphipoda (10 species of Gammaridea)	A
Pagurus sp.	N
Elassochirus tenuimanus	C
Hyas lyratus	C
Oregonia gracilis	C
Sclerocrangon boreas	F
Spirontocaris sp. (small)	N
Megalops of crabs	C

Comments: two *Pododesmus* occupying dead *Fusitriton* shell along with an *Elassochirus*; one of the *Podedesmus* brooding ∿50 eyed, shelled young.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

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APPENDIX II - TABLE VII

TAXA FROM BOTTOM SKIMMER STATION 07, 18.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Cnidaria	
Hydrozoa (1 specie)	I
Mollusca	
Glycymeris subobsoleta	I
Diplodonta orbellus	I
Nudibranch	I
Arthropoda	
Hippolytidae	I
Sclerocrangon boreas	I
Argis crassa	I
Oregonia gracilis	I
Elassochirus tenuimanus	I
Pagurus capillatus	I
Echinodermata	
Pteraster tesselatus	I

Comments: Short tow, hung up on rocks.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE VIII

TAXA FROM BOTTOM SKIMMER STATION 10, 31.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera (1 type)	I
Cnidaria	
Hydrozoa	F
Annelida	
Polynoidae	C
Terebellidae	I
Serpulidae	C
Nereidae	F
Syllidae	F
Mollusca	
Nudibranch	N
Velutina sp.	I
Placiphorella sp.	I
Micranellum sp.	F
Olivella baetica	I
Oenopota sp.	I
Humilaria kennerlyi	I
Glycymeris subobsoleta	I
Polinices sp.	I
Pododesmus macrochisma	I
Crepidula sp.	I
Arthropoda	
Hyppolytidae (small)	F
Cancer sp.	I
Oregonia gracilis (small)	C
Elassochirus tenuimanus	F
Isopoda	I
Gammaridae (∿8 species)	A
Caprellidae	A
Pagurus sp.	C
Sclerocrangon boreas	I
Pycnogonida	I
Ectoprocta (colony)	N
Echinodermata	
Crossaster papposus	I
Ophiuroidea	C
Strongylocentrotus droebachiensis	I

APPENDIX II - TABLE VIII

CONTINUED

Taxon	Relative Abundance[1]
Urochorda (4 types compound ascidian)	A

Comments: 1 stomach examined from *Gymnocanthus* sp. juvenile; 27 mm total length; contained 2 Pandalid shrimp; 3 Gammarid amphipods.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE IX

TAXA FROM BOTTOM SKIMMER STATION 11, 27.4 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera (3 species; one c.f. Grantiidae)	I
Cnidaria	
Hydrozoa (6 species)	A
Annelida	
Polynoidae	I
Nereidae	I
Phyllodocidae	I
Syllidae	I
Serpulidae	I
Rhynchocoela	I
Mollusca	
Hiatella arctica	F
Crepidula nummaria	I
Ischnochiton albus	I
Nudibranch	F
Fusitriton oregonensis	I
Nucella lamellosa	I
Amphissa columbiana	I
Musculus discors	F
Modiolus modiolus	F
Chlamys rubida	I
Velutina sp.	I
Arthopoda	
Balanus balanus	A
Pagurus sp.	C
Elassochirus tenuimanus	I
Cancer oregonensis	F
Hippolytidae	F
Gammaridea (8 species)	A
Caprellidae (♀♀ brooding eggs)	A
Isopoda	N
Oregonia gracilis	C
Lebbeus groenlandicus	I
Pagurus kennerlyi	I
Pugettia gracilis	I
Ectoprocta (colonial)	A

APPENDIX II - TABLE IX

CONTINUED

Taxon	Relative Abundance[1]
Echinodermata	
Ophiopholis aculeata	I
Henricia sp.	I
Urochorda (compound ascidian)	F

Comments: Main bulk of tow consisted of hydrozoans and ectoprocta.

[1]Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE X

TAXA FROM BOTTOM SKIMMER STATION 12, 31.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Foraminifera	A
Porifera	F
Cnidaria	
Hydrozoa (2 species)	A
Anthozoa	F
Annelida	
Owenidae	I
Polynoidae	I
Phyllodocidae	I
Serpulidae	I
Syllidae	I
Nephys sp.	I
Nereis sp.	N
Lumbrineris sp.	I
Eunoe sp.	F
Nephtyidae	I
Nereidae	N
Sabellidae	N
Serpulidae	A
Rhynchocoela	F
Mollusca	
Musculus discors	F
Modiolus modiolus	F
Natica sp.	I
Fusitriton oregonensis	F
Nucella lamellosa	F
Hiatella arctica	I
Humilaria kennerlyi (dead)	I
Glycymeris subobsoleta (dead)	F
Astarte sp. (dead)	I
Ischnochiton sp.	I
Pododesmus macrochisma	I
Polyplacophora (3 types)	N
Nudibranch	F
Unident. gastropod	N
Scaphopoda	N
Spisula polynyma (dead)	I
Pectinidae (dead)	I

APPENDIX II - TABLE X

CONTINUED

Taxon	Relative Abundance[1]
Mollusca (Cont'd)	
Trophonopsis sp. (dead)	I
Natica sp. (dead)	I
Fusitriton oregonensis (dead)	I
Fissurellidae (dead)	I
Arthropoda	
Gammaridae (6 species)	A
Eusiridae	A
Lysianassidae	A
Isopoda (2 species)	N
Balanus sp.	A
*most of decapods were zooea, megalops, and post-megalops juveniles	
Pandalidae	I
Sclerocrangon boreas	I
Elassochirus tenuimanus	F
Hyas lyratus (1 ♀ w/orange eggs)	I
Cancer oregonensis	I
Oregonia gracilis (♀ with eggs)	C
Cumacea (2 ♀♀ brooding young)	I
Pycnogonida (2 species)	F
Ectoprocta	
Flustra sp.	F
encrusting	A
leafy	N
Echinodermata	
Asteroidea	I
Echinoidea	I
Ophiuroidea	I
Strongylocentrotus droebachiensis	I
Urochorda	
Compound ascidian	I
Rhodosomatidae	I

Comments: Numerous larval decapods.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XI

TAXA FROM BOTTOM SKIMMER STATION 13, 36.6 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	I
Cnidaria	
Hydrozoa (6 species)	A
Annelida	
Polynoidae	I
Polychaeta	I
Serpulidae	C
Mollusca	
Fusitriton oregonensis	I
Olivella baetica	I
Polyplacophora	I
Hiatella arctica	I
Glycymeris subobsoleta	I
Mitrella gouldi	I
Arthropoda	
Cumacea	I
Oregonia gracilis	C
Cancer oregonensis	I
Balanus sp.	I
Hippolytidae	I
Pagurus sp.	C
Pagurus kennerlyi	I
Crangon dalli	I
Gammaridae	
Pycnogonida	
Elassochirus gilli	
Elassochirus tenuimanus	
Lebbeus groenlandicus	
Eualus sp.	
Pagurus capillatus	
Pugettia gracilis	
Ectoprocta	
encrusting	I
Flustra sp.	F
Alcyonidium sp.	I
Echinodermata	
Ophiuroidea	I
Strongylocentrotus droebachiensis	I

APPENDIX II - TABLE XI

CONTINUED

Taxon	Relative Abundance[1]
Urochorda	
Compound tunicate	I

Comments: Numerous amounts of brown and red algae fragments.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XII

TAXA FROM BOTTOM SKIMMER STATION 14, 31.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Cnidaria	
Hydrozoa (2 species)	I
Annelida	
Syllidae	I
Mollusca	
Olivella baetica	I
Musculus discors	I
Solariella obscura	I
Tonicella lineata	I
Arthropoda	
Elassochirus tenuimanus	I
Pagurus beringanus	I
Cancer oregonensis	I
Gammaridae	F
Pagurus sp.	F
Hippolytidae	I
Eualus sp.	I
Lebbeus groenlandicus	I
Spirontocaris prionota	I
Spirontocaris lamellicornis	I
Oregonia gracilis	I
Balanus balanus	I
Ectoprocta	
Microporina sp.	F
Flustrellidae	I
Echinodermata	
Ophiopholis aculeata	I
Strongylocentrotus droebachiensis	I
Urochorda	
Compound ascidian	A

---

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XIII

TAXA FROM BOTTOM SKIMMER STATION 14, 31.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Cnidaria	
Hydrozoa (2 species)	I
Annelida	
Syllidae	I
Mollusca	
Olivella baetica	I
Musculus discors	I
Solariella obscura	I
Tonicella lineata	I
Arthropoda	
Elassochirus tenuimanus	I
Pagurus beringanus	I
Cancer oregonensis	I
Gammaridae	F
Pagurus sp.	F
Hippolytidae	I
Eualus sp.	I
Lebbeus groenlandicus	I
Spirontocaris prionota	I
Spirontocaris lamellicornis	I
Oregonia gracilis	I
Balanus balanus	I
Ectoprocta	
Microporina sp.	F
Flustrellidae	I
Echinodermata	
Ophiopholis oculeata	I
Strongylocentrotus droebachiensis	I
Urochorda	
Compound ascidian	A

---

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XIV

TAXA FROM BOTTOM SKIMMER STATION 15, 29.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Foraminifera (3 species)	I
Porifera	I
Cnidaria	
Hydrozoa (by colony)	I
Annelida	
Lumbrineridae	I
Polynoidae	I
Syllidae	I
Serpulidae	I
Arthropoda	
Cumacea	N
Mysidacea	F
Isopoda	F
Crangon sp.	C
Oregonia sp.	F
Amphipoda	A
Hippolytidae	C
Oregonia gracilis	I
Pycnogonidae	I
Balanus sp.	I
Pagurus ochotensis	I
Mollusca	
Olivella baetica	A
Ectoprocta	
Microporina sp.	I
Alcyonidium sp.	I
Urochorda	
Compound ascidian	I

Comments: Numerous remains of pelecypods, gastropods, Ectoprocta, crustaceans, hydrozoans, and algae.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XV

TAXA FROM BOTTOM SKIMMER STATION 16, 40.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera (2 species)	I
Cnidaria	
Hydrozoa (by colony)	F
Anthozoa	I
Annelida	
Serpulidae	C
Phyllodocidae	C
Polynoidae	C
Nereidae	I
Syllidae	I
Arthropoda	
Caprellidea (large)	C
Gammaridea (∿10 species)	A
Elassochirus tenuimanus	F
Oregonia gracilis (♀♀ brooding eggs)	C
Hyas lyratus	F
Cancer sp.	F
Pandalidae (small)	F
Hippolytidae	F
Argis sp.	I
Balanus sp.	C
Mollusca	
Fusitriton oregonensis	I
Nudibranchs (small)	C
Cyclocardia crebricostata (dead)	I
Humilaria kennerlyi (dead)	I
Astarte sp. (dead)	I
Polinices sp. (dead; w/*Elassochirus* in them)	F
Crepidula sp.	I
Ectoprocta	
Echinodermata	
Asteroidea	I
Ophiuroidea	I
Strongylocentrotus droebachiensis	I

APPENDIX II - TABLE XV

CONTINUED

Taxon	Relative Abundance[1]
Urochorda	
Compound ascidian (1 species)	I

---

[1] Relative Abundance: I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XVI

TAXA FROM BOTTOM SKIMMER STATION 17, 29.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Cnidaria	
Hydrozoa (2 species)	I
Actiniidae	I
Mollusca	
Fusitriton oregonensis	I
Crepidula nummaria	I
Arthropoda	
Elassochirus tenuimanus	I
Balanus sp.	C
Argis crassa	I
Pagurus sp.	I
Elassochirus gilli	I
Eualus sp.	I
Pagurus kennerlyi	I
Pagurus confragosus	I
Ectoprocta (encrusting)	I
Urochorda	
Compound ascidian	I

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XVII

TAXA FROM BOTTOM SKIMMER STATION 18, 27.4 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Mollusca	
Glycymeris subobsoleta	F
Olivella baetica	I
Cyclocardia crebricostata	I
Tellina nuculoides	I
Arthropoda	
Oregonia gracilis	I
Crangon dalli	I
Hippolytidae	I

Comments: Red and green algae remains.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XVIII

TAXA FROM BOTTOM SKIMMER STATION 20, 29.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	I
Annelida	
Nereis sp.	I
Mollusca	
Glycymeris subobsoleta	A
Humilaria kennerlyi	I
Musculus discors	I
Astarte rollandi	I
Olivella baetica	C
TEllina nuculoides	I
Cyclocardia crebricostata	I
Unident. gastropod	I
Arthropoda	
Hippolytidae	I
Pagurus sp.	I
Gammaridae	I
Echinodermata	
Strongylocentrotus droebachiensis	I
Ectoprocta	
Flustrella gigantea	F
encrusting	I

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

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APPENDIX II - TABLE XIX

TAXA FROM BOTTOM SKIMMER STATION 21, 27.5 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera (many colonies of shell-encrusting type. Also, a form of sponge resembling a "cactus")	N
Hydrozoa (by colony, both leafy and dendroform)	A
Annelida	
Phyllodocidae	F
Nereidae	C
Sabellidae	I
Serpulidae	N
Polynoidae	I
Mollusca	
Hiatella arctica	I
Nudibranchs (small)	F
Pododesmus macrochisma	I
Polyplacophora	I
Glycymeris subobsoleta	I
Chlamys rubida	I
Cyclocardia crebricostata (dead)	I
Humilaria kennerlyi (dead)	I
Mya sp. (dead)	I
Beringius sp. (dead)	C
Nucella lamellosa (dead)	F
Fusitriton oregonensis (dead)	I
Naticidae sp. (dead)	I
Arthropoda	
Pycnogonida	I
Balanus sp.	N
Caprellidae	I
Gammaridae	A
Ischyroceridae	C
Oregonia gracilis	F
Cancer sp.	I
Pagurus sp.	N
Elassochirus tenuimanus	C
Pandalus sp. (small)	N
Spirontocaris sp. (small)	F
Sclerocrangon boreas (small)	F

APPENDIX II - TABLE XIX

CONTINUED

Taxon	Relative Abundance[1]
Ectoprocta (by colony)	A
Echinodermata	
Holothuroidea	I
Urochorda (by colony)	N
3 types, all compound ascidians	

Comments: Most shells were dead; 80% had been drilled.

---

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XX

TAXA FROM BOTTOM SKIMMER STATION 22, 27.5 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Cnidaria	
Hydrozoa (by colony)	F
Annelida	
Serpulidae	N
Nereidae	F
Sabellidae	F
Mollusca	
Margarites sp.	I
Glycymeris subobsoleta (dead)	N
Astarte sp. (dead)	A
Humilaria kennerlyi (dead)	I
Musculus discors	I
Arthropoda	
Gammaridea (5 species)	N
Pagurus sp. (small)	F
Pandalidae (small)	C
Sclerocrangon boreas	F
Hyas lyratus	I
Balanus sp.	F
Echinodermata	
Holothuroidea (small)	C
Ophiuroidea	F
Strongylocentrotus droebachiensis	F
Asteroidea	I
Urochorda (by colony) (2 types of compound ascidians)	N

Comments: Substrate: "Pea" gravel and smaller, no larger rocks.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XXI

TAXA FROM BOTTOM SKIMMER STATION 23, 23.8 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera (5 species; 2 of which are encrusting)	C
Cnidaria	
Hydrozoa (coral type and dendroform type)	F
Annelida	
Syllidae	F
Nereidae	I
Pectinariidae	I
Polynoidae	I
Serpulidae	F
Mollusca	
Pododesmus macrochisma	C
Calliostoma sp.	C
Fusitriton oregonensis	I
Beringius sp.	F
Nucella lamellosa	I
Musculus vernicosa (all very small, attached to kelp frond)	N
Astarte montagui	I
Arthropoda	
Pandalus sp.	C
Lebbeus groenlandicus	I
Spirontocaris sp.	N
Eualus sp.	I
Pagurus sp.	N
Elassochirus tenuimanus	F
Pugettia gracilis	I
Hyas lyratus (small)	C
Oregonia gracilis	C
Cancer sp. (small)	F
Amphipoda (5 species)	N
Balanus sp.	A
Ectoprocta (colony)	F
Echinodermata	
Strongylocentrotus droebachiensis	I

APPENDIX II - TABLE XXI

CONTINUED

Taxon	Relative Abundance[1]
Urochorda (short, finger-like compound ascidian dark, grape-like Rhodosomatid, *Chelyosoma* sp.)	F

Comments: High current area.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XXII

TAXA FROM BOTTOM SKIMMER STATION 24, 20.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera (3 types; including shell encruting form)	F
Cnidaria	
Hydrozoa (by colony) (2 types encrusting; 2 dendroform; 1 leafy)	N
Nemerteans	I
Annelida	
Serpulidae	C
Polynoidae	I
Nereidae	I
Syllidae	F
Mollusca	
Musculus vernicosa (many 1-2-3 yr. old *Musculus*	A
Nudibranchs (small)	I
Pododesmus macrochisma	I
Calliostoma sp.	I
Glycymeris subobsoleta (dead)	I
Naticidae (dead)	I
Arthropoda	
Caprellidea	I
Gammaridea	A
Pagurus sp.	C
Elassochirus tenuimanus	F
Cancer sp.	I
Cryptolithodes sp.	I
Pandalus sp.	F
Pycnogonida	I
Brachiopoda	I
Ectoprocta (by colony)	F
Echinodermata	
Ophiuroidea	I
Asteroidea	I

APPENDIX II - TABLE XXIII

TAXA FROM BOTTOM SKIMMER STATION 24, 20.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	F
(3 types; including shell encrusting form)	
Cnidaria	
Hydrozoa (by colony)	N
(2 types encrusting; 2 dendroforms; 1 leafy)	
Nemerteans	I
Annelida	
Serpulidae	C
Polynoidae	I
Nereidae	I
Syllidae	F
Mollusca	
Musculus vernicosa	A
(many 2-2-3 yr. old *Musculus*)	
Nudibranchs (small)	I
Pododesmus macrochisma	I
Calliostoma sp.	I
Glycymeris subobsoleta (dead)	I
Naticidae (dead)	I
Arthropoda	
Caprellidea	I
Gammaridea	A
Pagurus sp.	C
Elassochirus tenuimanus	F
Cancer sp.	I
Cryptolithodes sp.	I
Pandalus sp.	F
Pycnogonida	I
Brachiopoda	I
Ectoprocta (by colony)	F
Echinodermata	
Ophiuroidea	I
Asteroidea	I

APPENDIX II - TABLE XXIII

CONTINUED

Taxon	Relative Abundance[1]
Urochorda	
compound ascidian	I

---

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XXIV

TAXA FROM BOTTOM SKIMMER STATION 25, 27.5 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	I
Cnidaria	
Hydrozoa (by colonies) ("coral" like forms and leafy dendroform)	A
Annelida	
Gattyana iphionelloides	I
Euphrosine sp.	I
Sabellidae	I
Serpulidae	F
Mollusca	
Polyplacophora	F
Velutinidae	F
Pododesmus macrochisma (both minute and slightly larger)	F
Nudibranchs	I
Naticidae	F
Pelecypoda (very small)	N
Mya sp. (dead shell)	I
Humilaria kennerlyi (all small; dead)	F
Cyclocardia crebricostata (dead)	I
Glycymeris subobsoleta (dead)	F
Musculus discors (dead)	I
Oenopota (dead)	C
"*Fusinus*" type (dead)	N
Arthropoda	
Isopoda	I
Amphipoda (about 10 species)	
Caprellidae (one ♀ brooding eggs)	F
Ischyroceridae	F
Gammaridae	A
Pandalidae	C
Paguridae (mostly small - up to 2 cm long)	N
Cancer sp.	I
Atelecyclidae (post-megalops)	I
Balanus sp. (mostly small, recently settled ones)	N
Majidae	I

APPENDIX II - TABLE XXIV

CONTINUED

Taxon	Relative Abundance[1]
Ectoprocta (by colony)	A
Echinoderms	
Holothurians	I
Ophiuroidea	N
Urochorda (6 types, including 2 types of compound ascidians)	N

---

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XXV

TAXA FROM BOTTOM SKIMMER STATION 26, 29.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Cnidaria	
Hydrozoa	F
Annelida	
Maldanidae	F
Polychaeta	F
Mollusca	
Cyclocardia crassidens	I
Chlamys rubida	I
Kellia laperousii	I
Arthropoda	
Argis dentata	I
Hyas lyratus	I
Balanus sp.	I
Sclerocrangon boreas	F
Oregonia gracilis	I
Elassochirus tenuimanus	I
Pagurus kennerlyi	I
Pagurus sp.	I
Eualus sp.	A
Mysidacea	I
Spirontocaris lamellicornis	F
Spirontocaris prionota	F
Gammaridae	F
Sipunculida	I
Ectoprocta	
Flustra sp.	F
Echinodermata	
Ophiopholis aculeata	I

---

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XXVI

TAXA FROM BOTTOM SKIMMER STATION 27, 20.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera (shell-encrusting type most frequent; 2 other types)	C
Cnidaria	
Hydrozoa (by colony)	A
Annelida	
Polynoidae (3 species)	N
Syllidae	C
Mollusca	
Nudibranch	I
Bathybembix sp. (dead)	F
Musculus discors	I
Nucella lamellosa	F
Arthropoda	
Isopoda	I
Gammaridae (10 species)	A
Pagurus sp.	F
Elassochirus tenuimanus	I
Pandalus sp. (small)	N
Lebbeus groenlandicus (small)	C
Argis sp.	I
Balanus sp. (medium size)	C
Sclerocrangon boreas	I
Ectoprocta (by colony)	F
Brachiopoda	
Terebratalia sp.	I
Echinodermata	
Ophiopholis aculeata	C
Strongylocentrotus droebachiensis	I
Urochorda (compound tunicate)	I

---

[1] Relative Abundance: I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XXVII

TAXA FROM BOTTOM SKIMMER STATION 28, 40.3 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Porifera	A
(1 encrusting on *Oregonia* sp. 2 "free living" forms 1 shell-encrusting form)	
Cnidaria	
Hydrozoa (by colony)	A
Annelida	
Nereidae	C
Polynoidae	N
Sabellidae	F
Syllidae	C
Serpulidae	N
Mollusca	
Glycymeris subobsoleta	I
Chlamys rubida	I
Clinocardium sp.	F
Astarte sp.	I
Fusitriton oregonensis	F
Nucella lamellosa	I
Polinices sp.	C
Arthropoda	
Pycnogonida	C
Caprellidae	C
Gammaridae (∿8 species)	A
Pagurus spp.	N
Elassochirus tenuimanus	F
Cancer oregonensis	F
Cancer magister	C
Hyas lyratus (♀♀ brooding small eggs)	F
Oregonia gracilis	F
Pandalidae (small)	N
Pugettia gracilis	I
Ectoprocta (by colony)	A
(large, leafy, spongy textured form; 3 other forms)	
Echinodermata	
Strongylocentrotus droebachiensis	F
Crossater papposus	I

APPENDIX II - TABLE XXVII

CONTINUED

Taxon	Relative Abundance[1]
Echinodermata (Cont'd)	
Asteroidea (others)	I
Ophiuroidea	C
Urochorda	
Compound ascidians	F

Comments: 2 stomachs examined from *Anoplarchus* sp. (Stichaeidae)
♂; 91 mm total length; 6 salp-like Urochordates
♀; 74 mm total length; 2 types amphipods; 1 salp-like Urochordate; 1 *Pagurus* sp; 1 *Musculus discors* (?); 1 snail, (c.f. *Tachrynchus* sp.); remains of 2 crustaceans.

1 stomach from *Anoplagonus inermis* (Agonidae)
♂; 97 mm total length: contents - 1 crab megalops; 1 *Pagurus* sp.; 3 amphipods (Gammaridae) 2 pandalid shrimp.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

APPENDIX II - TABLE XXVIII

TAXA FROM BOTTOM SKIMMER STATION 29, 31.1 METERS, 10 AUGUST 1976

Sampling was conducted in the nearshore waters of outer Kenai Peninsula (Appendix II-Fig. 1) by the Alaska Department of Fish and Game with a 0.61 m wide by 0.91 m long sled-like bottom skimmer. Tows covered approximately 0.2 mile.

Taxon	Relative Abundance[1]
Mollusca	
Tellina nuculoides	A
Glycymeris subobsoleta (dead)	I
Clinocardium sp. (dead)	I
Crepidula sp. (dead)	I
Cyclocardia crebricostata (dead)	I
Bdringius sp. (dead)	
Arthropoda	
Majidae	I
Pagurus sp.	I
Echinodermata	
Ophiuroidea	I

Comments: Approximately 75% of substrate in sample composed of broken pieces of mollusc shells and *Balanus* sp. shells.

[1] Relative Abundance:
I = Infrequent (1-10 organisms)
F = Few (11-20)
C = Common (21-35)
N = Numerous (36-50)
A = Abundant (>51)

BEST DOCUMENT AVAILABLE

APPENDIX III

INVERTEBRATE TAXA OBTAINED BY PIPE DREDGE IN LOWER COOK INLET

APPENDIX III - TABLE I

INVERTEBRATE TAXA OBTAINED BY PIPE DREDGE IN LOWER COOK INLET

Taxon	April	October
Phylum Porifera		
Unidentified species	x	x
Phylum Cnidaria		
Class Hydrozoa		
Unidentified species	x	x
Family Lafoeidae		
Unidentified species	-	x
Family Sertulariidae		
Unidentified species	-	x
Sertularella sp.	-	x
Sertularia sp.	-	x
Abietinaria sp.	-	x
Family Plumulariidae		
Unidentified species	-	x
Family Stylasteridae		
Allopora sp.	x	x
Class Anthozoa		
Family Nephtheidae		
Eunephthya rubiformis	x	-
Family Primnoidae		
Stylatula gracile	-	x
Family Pennatulidae		
Ptilosarcus gurneyi	x	x
Family Actiniidae		
Unidentified species	x	x
Phylum Rhynchocoela		
Unidentified species	x	x
Phylum Annelida		
Class Polychaeta		
Unidentified species	x	x
Family Polynoidae		
Unidentified species	x	x
Family Sigalionidae		
Unidentified species	-	x
Family Nereidae		
Unidentified species	-	x
Nereis sp.	-	x
Family Nephtyidae		
Nephtys sp.	x	x

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Annelida (cont'd)		
Family Glyceridae		
Glycera sp.	-	x
Family Goniadidae		
Glycinde sp.	-	x
Family Onuphidae		
Unidentified species	-	x
Family Lumbrineridae		
Lumbrineris sp.	x	-
Family Arabellidae		
Unidentified species	-	x
Family Flabelligeridae		
Unidentified species	-	x
Family Opheliidae		
Unidentified species	-	x
Ophelia limacina	-	x
Family Sternaspidae		
Sternaspis scutata	x	x
Family Maldanidae		
Unidentified species	-	x
Family Pectinariidae		
Cistenides hyperborea	-	x
Family Sabellidae		
Unidentified species	x	x
Family Serpulidae		
Unidentified species	-	x
Class Hirudinea		
Unidentified species	-	x
Phylum Mollusca		
Unidentified species	x	-
Class Polyplacophora		
Family Ischnochitonidae		
Ischnochiton sp.	x	-
Ischnochiton trifidus	x	x
Family Mopaliidae		
Mopalia sp.	-	x
Mopalia ciliata	x	-
Mopalia cirrata	x	-
Mopalia muscosa	x	-
Class Pelecypoda		
Family Nuculidae		
Nucula tenuis	x	x

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Mollusca (cont'd)		
Family Nuculanidae		
Unidentified species	-	x
Nuculana minuta	x	x
Nuculana fossa	x	x
Portlandia sp.	-	x
Tindaria kennerlyi	-	x
Yoldia amygdalea	-	x
Yoldia hyperborea	x	-
Yoldia myalis	x	x
Yoldia scissurata	x	x
Yoldia thraciaeformis	-	x
Yoldia secunda	-	x
Family Glycymerididae		
Glycymeris subobsoleta	x	x
Family Mytilidae		
Mytilis edulis	-	x
Crenella decussata	-	x
Musculus discors	x	-
Musculus niger	x	x
Musculus corrugatus	-	x
Musculus marmoratus	-	x
Modiolus modiolus	x	x
Family Pectinidae		
Chlamys sp.	x	x
Chlamys rubida	x	x
Chlamys beringiana	x	-
Cyclopecten sp.	-	x
Propeamussium alaskense	-	x
Family Limidae		
Lima sabauriculata	-	x
Family Anomiidae		
Pododesmus macrochisma	-	x
Family Astartidae		
Astarte sp.	x	-
Astarte borealis	-	x
Astarte alaskensis	x	x
Astarte montagui	x	x
Astarte rollandi	x	x
Astarte bennettii	x	x
Astarte esquimalti	x	x
Family Carditidae		
Cyclocardia sp.	x	-
Cyclocardia ventricosa	x	x
Cyclocardia crebricostata	x	x
Cyclocardia crassidens	x	x

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Mollusca (cont'd)		
Family Lucinidae		
Parvilucina tenuisculpta	-	x
Family Thyasiridae		
Axinopsida serricata	-	x
Thyasira flexuosa	x	x
Family Kelliidae		
Kellia laperousi	x	-
Family Montacutidae		
Mysella sp.	-	x
Odontogena borealis	-	x
Family Cardiidae		
Clinocardium sp.	x	-
Clinocardium ciliatum	x	x
Clinocardium nuttallii	-	x
Clinocardium californiense	x	x
Serripes groenlandicus	x	x
Family Veneridae		
Saxidomus gigantea	-	x
Liocyma fluctuosa	x	x
Psephidia lordi	-	x
Humilaria kennerlyi	x	x
Protothaca staminea	x	x
Family Mactridae		
Spisula polynyma	x	x
Family Tellinidae		
Macoma sp.	x	x
Macoma calcarea	x	x
Macoma elimata	-	x
Macoma brota	-	x
Macoma obliqua	x	x
Macoma moesta alaskana	-	x
Macoma balthica	x	-
Tellina nuculoides	x	x
Family Solenidae		
Siliqua alta	x	-
Siliqua sloati	-	x
Family Myidae		
Mya truncata	x	-
Mya priapus	x	x
Family Hiatellidae		
Hiatella arctica	x	x
Family Pandoridae		
Pandora bilirata	-	x
Family Lyonsiidae		
Lyonsia sp.	x	-

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Mollusca (cont'd)		
Class Gastropoda		
Unidentified species	x	-
Family Fissurellidae		
Puncturella galeata	x	x
Family Lepetidae		
Cryptobranchia concentrica	-	x
Cryptobranchia alba	x	-
Family Trochidae		
Margarites olivaceus	-	x
Margarites pupillus	x	-
Margarites costalis	x	-
Solariella obscura	x	x
Solariella varicosa	x	x
Family Cocculinidae		
Cocculina casanica	-	x
Family Eulimidae		
Balcis sp.	-	x
Family Calyptraeidae		
Crepidula nummaria	-	x
Family Trichotropididae		
Unidentified species	-	x
Trichotropis cancellata	x	-
Family Naticidae		
Amauropsis purpurea	-	x
Natica clausa	x	x
Polinices pallida	x	x
Family Velutinidae		
Velutina sp.	-	x
Velutina lanigera	x	-
Family Cymatiidae		
Fusitriton oregonensis	x	x
Family Muricidae		
Boreotrophon clathratus	x	-
Boreotrophon stuarti	x	-
Boreotrophon smithii	x	-
Boreotrophon multicostalis	x	-
Boreotrophon pacificus	x	x
Boreotrophon lasius	x	x
Family Thaididae		
Nucella lamellosa	x	x
Family Buccinidae		
Buccinum plectrum	x	x

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Mollusca (cont'd)		
Family Neptuneidae		
Beringius sp.	x	-
Beringius kennicotti	-	x
Neptunea sp.	x	-
Neptunea lyrata	x	x
Neptunea ventricosa	x	x
Plicifusus sp.	x	-
Family Columbellidae		
Amphissa columbiana	x	x
Mitrella gouldi	x	x
Family Volutomitridae		
Volutomitra alaskana	x	x
Family Olividae		
Olivella baetica	x	x
Family Cancellariidae		
Admete sp.	-	x
Admete couthouyi	x	-
Family Turridae		
Suavodrillia kennicottii	x	-
Oenopota sp.	x	x
Oenopota decussata	-	x
Oenopota turricula	x	-
Propebela sp.	-	x
Family Pyramidellidae		
Turbonilla torquata	-	x
Family Retusidae		
Retusa sp.	-	x
Family Diaphanidae		
Diaphana sp.	-	x
Family Scaphandridae		
Cylichna alba	-	x
Cylichna attonsa	-	x
Family Dorididae		
Unidentified species	-	x
Class Scaphopoda		
Family Dentaliidae		
Dentalium sp.	-	x
Phylum Arthropoda		
Class Pycnogonida		
Family Pycnogonidae		
Unidentified species	-	x

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Arthropoda (cont'd)		
Class Crustacea		
Order Thoracica		
Unidentified species	-	x
Family Balanidae		
Balanus sp.	x	x
Balanus crenatus	x	-
Balanus evermani	x	-
Balanus hesperius	-	x
Balanus rostratus	x	x
Order Cumacea		
Unidentified species	-	x
Order Isopoda		
Family Aegidae		
Rocinela augustata	-	x
Order Amphipoda		
Unidentified species	x	x
Family Ampeliscidae		
Ampelisca birulai	x	-
Byblis gaimandi	x	-
Family Corophiidae		
Ericthonius sp.	-	x
Family Gammaridae		
Anisogammarus sp.	-	x
Melita sp.	-	x
Melita dentata	x	-
Family Lysianassidae		
Anonyx sp.	-	x
Family Ischyroceridae		
Ischyrocerus sp.	x	-
Family Talitridae		
Unidentified species	-	x
Family Caprellidae		
Unidentified species	-	x
Order Decapoda		
Unidentified species	-	x
Family Pandalidae		
Pandalus sp.	-	x
Pandalus borealis	-	x
Pandalus goniurus	-	x
Pandalus hypsinotus	-	x
Pandalopsis dispar	-	x

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Arthropoda (cont'd)		
Family Hippolytidae		
Spirontocaris lamellicornis	-	x
Lebbeus groenlandicus	x	x
Eualus sp.	-	x
Eualus herdmani	-	x
Eualus stoneyi	-	x
Heptacarpus tridens	-	x
Family Crangonidae		
Crangon dalli	x	x
Sclerocrangon boreas	x	x
Family Calianassidae		
Unidentified species	-	x
Family Paguridae		
Unidentified species	x	-
Pagurus sp.	x	x
Pagurus ochotensis	x	x
Pagurus aleuticus	-	x
Pagurus capillatus	x	x
Pagurus kennerlyi	x	x
Pagurus beringanus	x	x
Pagurus trigonocheirus	-	x
Elassochirus tenuimanus	x	x
Family Lithodidae		
Paralithodes camtschatica	x	-
Rhinolithodes wosnessenskii	x	-
Family Majidae		
Oregonia gracilis	x	x
Hyas lyratus	x	x
Chionoecetes bairdi	x	x
Family Cancridae		
Cancer sp.	-	x
Cancer magister	-	x
Cancer oregonensis	x	x
Family Pinnotheridae		
Pinnixa sp.	x	-
Pinnixa occidentalis	-	x
Phylum Sipunculida		
Unidentified species	x	-
Golfingia sp.	-	x
Golfingia margaritacea	-	x
Phascolion strombi	-	x

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Echiuroidea		
Family Echiuridae		
Echiurus echiurus alaskensis	-	x
Phylum Ectoprocta		
Unidentified species	x	x
Class Cheilostomata		
Family Flustridae		
Unidentified species	-	x
Family Microporidae		
Microporina sp.	-	x
Class Cyclostomata		
Family Diastoporidae		
Unidentified species	-	x
Family Heteroporidae		
Heteropora sp.	-	x
Class Ctenostoma		
Family Alcyonidiidae		
Alcyonidium sp.	x	x
Family Flustrellidae		
Flustrella sp.	x	-
Flustrella gigantea	-	x
Phylum Brachiopoda		
Unidentified species	-	x
Class Articulata		
Family Cancellothyrididae		
Terebratulina unguicula	x	x
Family Dallinidae		
Laqueus californianus	x	x
Terebratalia transversa	x	x
Phylum Echinodermata		
Unidentified species	-	x
Class Asteroidea		
Family Porcellanasteridae		
Ctenodiscus crispatus	x	x
Family Echinasteridae		
Henricia sp.	-	x
Henricia leviuscula	x	x
Family Solasteridae		
Crossaster papposus	x	x

APPENDIX III - TABLE I

CONTINUED

Taxon	April	October
Phylum Echinodermata (cont'd)		
Family Asteridae		
Leptasterias sp.	x	-
Leptasterias polaris	x	x
Class Echinoidea		
Family Echinarachniidae		
Echinarachnius parma	x	x
Family Strongylocentrotidae		
Strongylocentrotus droebachiensis	x	x
Strongylocentrotus franciscanus	-	x
Class Ophiuroidea		
Unidentified species	-	x
Family Amphiuridae		
Amphiopholis sp.	x	-
Amphipholis pugetana	-	x
Diamphiodia craterodmeta	-	x
Diamphiodia periercta	-	x
Family Gorgonocephalidae		
Gorgonocephalus caryi	-	x
Family Ophiactidae		
Ophiopholis sp.	x	-
Ophiopholis aculeata	x	x
Family Ophiuridae		
Unidentified species	x	-
Ophiopenia disacantha	-	x
Ophiura sp.	x	x
Ophiura sarsi	x	x
Class Holothuroidea		
Family Synaptidae		
Unidentified species	-	x
Family Cucumariidae		
Unidentified species	x	-
Cucumaria sp.	x	x
Cucumaria calcigera	-	x
Phylum Chordata		
Class Ascidiacea		
Unidentified species	x	x
Family Rhodosomatidae		
Chelyosoma sp.	x	-
Family Styelidae		
Unidentified species	-	x
Family Pyuridae		
Halocynthia igaboja	-	x
Total	145	212

APPENDIX IV

INVESTIGATIONS ON SHALLOW SUBTIDAL HABITATS AND ASSEMBLAGES IN LOWER COOK INLET

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INVESTIGATIONS ON SHALLOW SUBTIDAL HABITATS AND ASSEMBLAGES IN LOWER COOK INLET

by

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For

Institute of Marine Sciences
University of Alaska
Anchorage, Alaska

February 11, 1980

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The main objectives of this study were to expand the available information base on shallow subtidal habitats in Kachemak and Kamishak Bays, to describe the large horse mussel (Modiolus) assemblage in more detail, and to examine the trophic structure of shallow subtidal assemblages. Major emphasis was given to rocky substrates.

Three important types of assemblages were observed on shallow subtidal rocky habitats. The southern Kachemak Bay assemblage, strongly resembling shallow subtidal rocky assemblages in the northeastern Pacific, was strongly dominated by kelps and is probably least vulnerable to impingement of oil contamination and least sensitive to the effects of an acute oil spill. The northern Kachemak Bay assemblage included an important kelp component but was strongly dominated by suspension feeders. Standing stocks of suspension feeders were very high. This assemblage is probably moderately vulnerable to impingement but highly sensitive to the effects of an acute oil spill. The western Cook Inlet assemblage, strongly resembling epifaunal assemblages in the Bering and Beaufort Seas, was strongly dominated by suspension feeders. Except in the intertidal and very shallow subtidal zones, kelps were absent. The area is probably highly vulnerable to impingement of oil contamination and highly sensitive to the effects of acute spills. Acute spills from drilling platforms, terminal facilities, tankers, or pipelines probably constitute the greatest threat to shallow subtidal assemblages in lower Cook Inlet. Other oil-related impacts are of lesser concern because of the remoteness of these assemblages from the activities and the high degree of turbulence in the overlying water masses.

II. INTRODUCTION

Counterbalancing the economic and political gain that could be realized from development of potential oil and gas reserves in lower Cook Inlet is the very real prospect that the intertidal and shallow subtidal habitats of that estuary may be exposed to large-scale chronic or acute contamination. The magnitude of this potential problem is dependent primarily on the overall importance of the littoral* zone and its component habitats to the biological systems of the inlet and associated areas and, secondarily, on the actual sensitivity of these habitats to the potential perturbations. Man tends to rank the importance of a resource according to his own observable utilization of the resource. Since one of the most important human uses of intertidal resources in lower Cook Inlet directly perceived by most individuals is clamming, and since only small segments of the coastline are used, the importance of intertidal habitats is often considered to be low. However, the actual importance and sensitivity of the zone cannot be evaluated until it has been adequately described and its relationships to other systems are at least generally defined. It is clear from experience throughout the world that severe observable impacts of oil-related problems can occur in the littoral zone (Boesch, Hershner and Milgram 1974; Smith 1968; Nelson-Smith 1972; NAS 1975).

A. NATURE AND SCOPE

Littoral habitats and assemblages in lower Cook Inlet were generally undescribed until Dames & Moore biologists commenced rocky intertidal studies in Kachemak Bay in 1974 (Rosenthal and Lees 1976). Soft intertidal habitats (sand and mud) were not studied until spring and summer of 1976, when the Bureau of Land Management (BLM) initiated a reconnaissance of physical, chemical, and biological systems in lower Cook Inlet through its Outer Continental Shelf Environmental Assessment Program (OCSEAP).

---

*Littoral as used in this document refers to the intertidal and shallow subtidal zone, out to a depth of 25 m.

These studies were initially designed to collect the information necessary to permit BLM to write the Environmental Impact Statement for the OCS oil and gas lease sale. As part of the reconnaissance, the first phase of this study (R. U. #417) was designed to examine and describe beaches representative of the major littoral habitats in lower Cook Inlet (Lees and Houghton 1977).

Additional site-specific studies followed, but did not permit examination of the diversity of habitat types suspected in the littoral zone throughout lower Cook Inlet. Furthermore, because of the breadth of the scope of these studies, certain specific aspects could not be addressed, leaving some important data gaps.

B. OBJECTIVES

The specific objectives of this study have been to:

1. Examine more shallow subtidal locations in Kachemak and Kamishak Bays in order to improve our understanding of the range of variation of the community types existing there;

2. Study populations of the horse mussel *Modiolus modiolus* and benthic assemblages associated with it; and

3. Expand the data base on the trophic structure of shallow subtidal assemblages in Kachemak and Kamishak Bays.

III. CURRENT STATE OF KNOWLEDGE

Various facets of the major littoral assemblages in lower Cook Inlet have been described in reports since 1975. However, at this time all of the work has been descriptive, based on qualitative and/or quantitative observations. Critical examination of the processes shaping the littoral communities and the potential for impact from OCS oil and gas development awaits experimental studies of the interrelationships and interactions among the various organisms and assemblages and the physical and chemical environment influencing them.

Most of the information describing littoral communities in lower Cook Inlet is included in reports by Rosenthal and Lees (1976, 1979), Lees and Houghton (1977), and Lees et al. (1979a).Additional information is included in Lees (1976, 1977, and MS), Erikson (1977), Sundberg and Clausen (1977), Cunning (1977), Driskell and Lees (1977), Sanger, Jones and Wiswar (1979). These reports provide insights into the composition, structure, function, seasonal variations, and production of the biological assemblages in lagoons, bays, mud flats, kelp beds, sand beaches rocky intertidal and subtidal habitats, mussel beds and cobble beaches; and the distribution, seasonal abundance and diet of many associated birds. These reports indicate that the littoral assemblages in Lower Cook Inlet are generally diverse, highly dynamic and highly productive, especially the rock intertidal habitats, the rocky subtidal areas in Kachemak Bay, and the mud flats.

Rosenthal and Lees (1976) studied several littoral habitats in Kachemak Bay from 1974 to 1976. The majority of their work was on rocky intertidal and subtidal habitat on both the north and south sides of the bay. The report indicates that vegetative cover and floral composition on rocky habitats varied considerably on a seasonal basis; greatest cover occurred in the summer. A similar pattern was reported for sessile invertebrates such as barnacles and mussels. In addition, the report provides a preliminary description of trophic structure on rocky habitats and seasonal variation in predation rates and predator occurrence. Furthermore, strong differences were reported between the composition and productivity of the assemblages on the north and south borders on Kachemak Bay, and high standing stocks of the horse mussel Modiolus modiolus on the north shelf were noted.

The intertidal reconnaissance in lower Cook Inlet indicated that most of the rocky intertidal habitats are located in Kachemak Bay and Kennedy Entrance, on the east, and in Kamishak Bay, on the west (Lees and Houghton 1977). The intertidal areas north of Kachemak and Kamishak Bays are mainly soft, with the lower beaches in exposed areas being sand and in protected areas, mud. At lower tidal levels, approximately 50 percent of the shoreline on the west side is mud flats, largely as a consequence of the number of bays that intrude deeply into the coastline. North of Kachemak Bay on the east side of the Inlet, the smooth shoreline is interrupted by just a few rivers and streams, and the lower tidal levels are almost exclusively sandy. The upper beaches (above MLLW) for a large proportion of the shoreline in the lower Inlet are characterized by a steeper slope of poorly sorted sand, coarse gravel, and cobbles. Based on the slope, grain size, and impoverished fauna, this habitat appears to be the least stable of the soft, or unconsolidated, intertidal substrates in lower Cook Inlet.

Lees and Houghton (1977) reported important differences in algal distribution and production in lower Cook Inlet. The algal assemblages in the southeastern quadrant of the inlet (including Kachemak Bay) appeared much more productive than in the remaining quadrants, where significant algal production was generally limited to depths of less than 3 m. These patterns were attributed to both turbidity and available substrate. They also suggest that macrophyte production in the SE quadrant of lower Cook Inlet might be of importance in the overall scheme of plant production and trophic dynamics of the inlet.

In addition, the report of Lees (1976) that the subtidal epifauna on the west side of the inlet bore a strong resemblance to the assemblages described by MacGinitie (1955) for the Beaufort Sea was corroborated by additional diving studies.

The reconnaissance study further indicated sharp differences between the biotic assemblages of the sand and mud habitats. Although both habitats were characterized by detritus-based assemblages, and depended to varying degrees upon organic debris produced in other areas, the sand beaches supported a rather impoverished assemblage with low biomass whereas the mud beaches supported a more diverse assemblage with moderate biomass. The sand beach faunas were dominated by polychaete worms and gammarid amphipods whereas the mud flat faunas were heavily dominated by clams. The lower level of the gravel upper beach appeared to be dominated by a gammarid amphipod and an isopod, both of which formed dense aggregations under large cobbles (Lees and Houghton 1977).

It is suspected, based on the reconnaissance study, that intertidal resources are important to several non-resident or migratory organisms. For instance, migratory shorebirds, gulls, and sea ducks feed heavily on organisms living in soft intertidal substrates, especially mud. During spring migration, at least one group is feeding there during each stage of the tide. Fish and crustaceans move into the intertidal zone during high tides to feed and some species remain there during low tide (Green 1968). Several investigators have reported that mud flats are important feeding areas for juvenile salmon (Sibert et al. 1977; Kaczynski et al. 1973). However, only preliminary descriptions of the various systems examined were provided by the reconnaissance studies.

The major objective of the research described by Lees et al. (1979a) was to more fully describe the systems at specific sites, and to identify the more important relationships and processes operating in these assemblages. This necessitated a fairly detailed examination of seasonal changes in species composition and structure. Trophic relationships were not emphasized because the most important predators (birds and fish) are the object of other research units.

Lees et al. (1979a), reported on seasonal, zonal, and geographic variations in abundance, relative cover and biomass of biotic assemblages on rock, sand, and mud substrates in lower Cook Inlet, They also discussed seasonal variations in growth rates of three major kelp species (Alaria fistulosa, Agarum cribrosum and Laminaria groenlandica) and primary production of Alaria, observing that growth rates of the blades of these three species were highest from March through June and declined to very low rates in late summer through mid-winter. They pointed out that kelps accounted for a major proportion of algal standing stocks on both intertidal and subtidal rocky substrates in Kachemak Bay. They described the infaunal biomass patterns on sand and mud beaches, noting that mud flats support high standing stocks of the clams Mya spp. and Macoma balthica, and that the infaunal assemblages on sand beaches are rather impoverished.

Rosenthal and Lees (1979) investigated composition, abundance and trophic structure of inshore fish assemblages in lower Cook Inlet, particularly on rocky habitats in Kachemak Bay. Major groups included greenlings, ronquils, sculpins and flatfish. Fish densities and species diversity were highest in summer and lowest in winter. Most species appeared to move to deeper water in the winter. Feeding efforts tended to concentrate on epibenthic forms, especially shrimp and crabs.

The importance of the interactions between birds and the littoral zone has been noted by Erikson (1977), Sanger, Jones and Wiswar (1979), and Lees et al. (1979a). Erikson (1977) reported on composition, seasonal variations in distribution and abundance of bird assemblages in Kachemak Bay and lower Cook Inlet. The most important year-round groups in littoral habitats included sea ducks and gulls, but shorebirds are seasonally very abundant. Sanger, Jones and Wiswar (1979) examined food habits of a number of species and found that sea ducks fed largely on heavily infaunal and sessile epifaunal molluscs whereas gulls had a more catholic diet. Of particular importance to several sea ducks are the clam Macoma balthica and the mussel Mytilus edulis.

IV. PHYSICAL SETTING AND STUDY AREAS

Cook Inlet is a large tidal estuary located on the northwest edge of the Gulf of Alaska in south-central Alaska. The axis of the inlet trends north-northeast to south-southwest and is approximately 330 km long, increasing in width from 36 km in the north to 83 km in the south. The inlet, geographically divided into the upper and lower portions by the East and West Forelands, is bordered by extensive tidal marshes, lowlands with numerous lakes, and glaciated mountains. Large tidal marshes and mud flats are common along much of the western and northern margins of the upper inlet. Most tributary streams are heavily laden with silt and seasonally contribute heavy sediment loads, especially in the upper inlet. The range of the semi-diurnal tides is extreme with a normal amplitude of 9 m (30 ft) at the head of the inlet. Tidally generated currents are strong. The general net current pattern brings oceanic water through Kennedy Entrance and northward along the east side of the inlet. Turbid and usually colder waters from the upper inlet move generally southward along the west side of the inlet and through Kamishak Bay, leaving the inlet through Shelikov Strait (BLM, 1976). It has been suggested, however, that a considerable proportion of the oceanic water entering Cook Inlet on an incoming tide is pumped back out on the subsequent outgoing tide (BLM, 1976). During the winter and spring, ice conditions are much more harsh on the west side of the inlet. Thus, the oceanographic conditions on each side of the inlet are significantly different, resulting in notable differences in the nature of intertidal and shallow water biological communities.

A. EAST SIDE OF INLET - ROCK

All surveys on the east side of Cook Inlet were conducted in Kachemak Bay. The sites included Jakolof Bay, a station west of Barabara Point, Archimanditof Shoals, Bluff Point and Troublesome Creek. These areas comprise a broad variety of habitat types. Other sites that have been examined since 1974 included Seldovia Point, Cohen Island, and Gull Island.

1. Jakolof Bay

Jakolof Bay, less than 0.5 km wide and only about 3.25 km long, is located on the south side of Kachemak Bay, approximately 18.5 km due south of the City of Homer (Figure 1). The bay is generally shallow and has a narrow entrance less than 12 meters deep. The head of the bay is shallow and fed by a freshwater stream. The shoreline is rocky and wooded.

Most observations and underwater sampling were confined to the shallow reef that projects off the rocky headland on the northwest side of the bay. This area has been studied since 1974 (Rosenthal and Lees 1976). The reef, marked by a small islet, nearly occludes the entrance to the bay. An overhead power transmission line crossing the reef is another useful landmark. A prominent kelp stand grows along the reef with its floating canopy usually visable on a slack tide. The substrate underlying the vegetative canopy is composed of bedrock, cobbles, and small to medium sized boulders (Rosenthal and Lees 1976). Between this terrace and the floor of the channel is a moderate slope of talus or bedrock. Fine sands and calcareous shell debris are conspicuous features at certain locations on the reef. Strong tidal currents are typical of this location, especially the entrance channel. On either a flood or ebb tide the floating portion of the kelp bed is usually pulled below the sea surface. The currents generated during spring tide cycles are estimated to range between 2 and 3 knots. Subsurface water movement is greatest across the rock reef. The currents encourage the proliferation of suspension feeding forms (i.e., sea anemones, barnacles, sabellid polychaetes, and nestling clams), which are visual dominants at this location and depth (Rosenthal and Lees 1976). In the shallow areas, the kelp *Alaria fistulosa* form a heavy growth with a thick, floating canopy in the summer. The algal understory beneath the *Alaria* bed is also thick, comprising numerous species of brown, red, and green algae.

Steel bands and bark from floating rafts of logs being transported out of Jakolof Bay have accumulated on the sea floor. Since 1974 these objects have continued to collect on the reef; accumulation and decay rates of these materials are unknown (Rosenthal and Lees 1976).

2. Barabara Point

The kelp bed at Barabara Point is continuous with that at Seldovia Point (Figure 1), but is strongly dominated by bull kelp. However, currents are considerably dampened by the effects of the large kelp bed and thus the substrate and understory algae are rather more silty than at Seldovia Point. The depth of the area surveyed was about 10 m. The boulder-bedrock substrate has numerous crevices and ledges and offers considerable bottom relief. Many of the outcrops appear to be low-grade coal well overgrown with encrusting coralline algae and epifaunal invertebrates.

3. The Northern Shelf

On the north side of Kachemak Bay, west of Homer Spit, is a broad, rocky shelf (Figure 1). Called herein the northern shelf, this relatively flat bench extends from Archimandritof Shoals, off the west side of the Spit, northwest to its widest point off Troublesome Creek and Anchor Point. The substrate of the shelf is flat and characterized by rock, which predominated at every site. Cobble and boulder fields were the principal type of structure observed, and patches of shell debris were also common. In several areas, the boulders and associated outcrops were composed of coal. During winter storms, large quantities of coal are broken up and moved across the shelf to the beach. Evidence of silt deposition varied locally. Generally algal cover was substantially less on the shelf than in the study areas on the south side of the bay. The physical and chemical charactertistics of the seawater bathing the shelf become more oceanic toward its western end.

B. WEST SIDE OF INLET - ROCK

All of the systematic work on rock habitat on the west side of Cook Inlet was conducted in Kamishak Bay at three key locations, namely, Scott Island, Knoll Head Lagoon, and White Gull Island. A number of other sites have been examined on the west side of cook Inlet since 1975 (Lees and Houghton 1977), including several sites each at Chinitna, Iniskin, and Bruin

Bays and near the mouth of the Douglas River. These areas comprise a broad variety of habitat types and biotic assemblages.

Turbidity and weather conditions in Kamishak Bay and on the west side of the inlet were generally poor for conducting diving surveys. Generally, they act to preclude satisfactory work for much of the year. In April, we spent six days at Scott Island and cancelled all dive activities. We returned in June, dove for three days under marginal conditions before cancelling the remaining scheduled activities because of turbidity. In August, we were able to conduct quantitative surveys at several locations, but the areas were barely workable because of turbidity.

1. Scott Island

Scott Island is a low, relatively flat island of moderate size (30 hectares) in the entrance to Iniskin Bay (Figure 1). Large reefs marked by a number of small islets and emergent rocks provide the shorelines of the island considerable protection from the oceanic swells crossing lower Cook Inlet from the ocean entrances, especially during tow tides. The island is heavily wooded and is protected around much of its perimeter by steep cliffs, some 30 m in height, that extend well down into the intertidal zone. Small gravelly beaches on the landward (NE, N, and W) sides of the island provide a boat landing and access to the wooded top of the island.

From the base of a cliff at the southwestern corner of the island, a rock bench slopes generally seaward. The upper level of the bench supports Fucus. The middle level supports Rhodymenia. The lowest portion of the bench extends to about -0.5 m MLLW. Several large shallow tide pools scattered about this bench support Laminaria groenlandica. Below this level, scattered channels of shelly gravel and sand interspersed with bedrock extend subtidally. Bedrock of Scott Island consists of a conglomerate of cobbles fist-sized or larger firmly cemented in a hardened sandy matrix. Very little loose material or even boulder-sized rocks are present except in the channels. Subtidally, scoured sand predominates and rock is limited to scattered medium to large boulders extending up to 2 m above the sand.

2. Knoll Head Lagoon

Knoll Head is a rocky headland rising steeply to 890 m in elevation on the west side of the entrance to Iniskin Bay (Figure 1). The complex shoreline west from the mouth of Iniskin comprises vertical rock cliffs, angular sea stacks, rocky islets and reefs; and just east of the major unnamed stream between Knoll Head and Iliamna Bay are two moderate-sized embayments with gravel and even muddy sand beaches alternating with vertical rock faces. East of these bays is a less protected cove opening to the south that we have named Knoll Head Lagoon. From the base of a 5- to 6-m cliff, an undulating bedrock beach extends seaward as a descending series of rock benches separated by lower-lying channels. The upper level supported dense Fucus. The middle level, on a lower, more gently rounded ridge, was largely in the Rhodymenia zone. However, drier outcrops supported considerable Fucus, while wetter pockets and channels were dominated by Laminaria. The lowest level sampled was also in the Rhodymenia zone on a similar but smaller rounded rock ridge at about MLLW. Below MLLW a series of low bouldery tide pools break up the beach pattern.

Offshore, a series of low reefs oriented nearly parallel to shore protects these beaches from southerly swells originating at the ocean entrances, except when the tide is fairly high.

Subtidal surveys were conducted between the intertidal zone and the offshore reefs. Bedrock extends down to a depth of about 6 m, where silty gravel becomes the dominant substrate.

3. White Gull Island

White Gull Island is a small low-lying island situated in mid-channel just inside the entrance to the Iliamna-Cottonwood Bay complex (Figure 1). The protected western and northern sides of the island have moderately sloped beaches of cobble, gravel and coarse sand interspersed with bedrock ribs and outcrops. The eastern shore, facing lower Cook Inlet and with little protection from swells coming through the ocean entrances, consists of a coarse cobble upper beach and an irregular lower bedrock bench punctuated with a coarse cobble upper beach and an irregular lower bedrock bench punctuated with pinnacles and outcrops and interspersed with channels and tide pools. The pinnacles and outcroppings provide some protection for the cobble upper beach.

The study transect was on the exposed side of the island. It ran due east across the bench between two elevated rock outcrops that extend to or above the high tide line. Permanent markers (20-cm steel spikes) were placed at two levels. The upper level was in the *Fucus* zone on an irregular rock bench marked by ridges and gullies varying in elevation by up to 1 m. The lower level was on a relatively flat rock bench outside of the protecting rock pinnacles. This bench, near or slightly above MLLW, contains numerous tide pools and channels. The outer lip of this bench is a vertical to overhanging precipice dropping to a depth of about 10 m. From the base of this wall, a talus bottom with small to large boulders slopes down to about 13 m. Diving surveys were conducted mainly along the base of the wall on the talus slope. Because of the steepness and irregularity of the habitat, the complexity of the fauna, and the degree of siltation, quantitative work was not attempted.

4. Black Reef

Black Reef, a rock outcrop northeast of the entrance to Iliamna Bay, (Figure 1), extends above the water surface in several places. It is a series of bedrock pinnacles surrounded by talus slopes of medium-to large-sized boulders. The pinnacles have vertical or overhanging sides to a depth of about 7 m. The seafloor surrounding the reef structure is about 10 to 15 m deep and composed of silty sand with ripple marks.

5. Turtle Reef

Turtle Reef is a series of rock reefs and outcroppings fringing the shore of South Head, the southern headland guarding the entrance to Iliamna Bay (Figure 1). The reef extends to about 1 km offshore and most of the rocks are emersed at low tide. The intertidal zone on the SW side of the reef was examined qualitatively by scuba techniques during high tide in a futile attempt to assess subtidal conditions.

V. METHODS

A. FIELD COLLECTION PROCEDURES

Both quantitative and qualitative data collection techniques were utilized at various study sites. The most commonly used quantitative technique was enumeration of organisms within 1/4 m^2 quadrats placed randomly along a transect. Within each quadrat, the number and/or relative cover of each observable taxon were recorded and all plants attached within the frame were removed and bagged for subsequent weighing. Additional quadrats from 1/16 m^2 to 30 m^2 were sometimes utilized to obtain better estimates of density and cover for the less common plants and animals in the study area.

Samples of *Modiolus* were collected to establish biomass, size distributions and density estimates. Both 1/4 m^2 and mass removal techniques were used. Qualitative extralimital species and feeding observations were recorded.

The diet of sea stars was examined by 1) turning an animal over to examine for food items contained under or within the folds of the everted stomach, or 2) gently palpating the aboral surface to cause extrusion of the stomach contents.

B. LABORATORY PROCEDURES

Plant samples from each quadrat were handled and recorded individually. Drained wet weight and length were measured for each laminarian; aggregate drained wet weights were measured for all other algae.

Length of various invertebrate species was measured to establish size distribution. Preserved (10 percent formalin) whole weights, wet tissue and dry tissue weights were measured for *Modiolus*.

C. DATA ANALYSIS

Mean and standard deviation were used to summarize such parameters as abundance, relative cover and biomass. Relationships between parameters such as wet tissue weight vs. individual size were derived using linear regression techniques, usually with a $\log_{10}$ transformation to both variables ($\log Y = b \log X + a$).

Size frequency analysis of population distribution was usually accomplished graphically while similarities between populations were tested using a nonparametric Kolmogorov-Smirnov two-way test of significance.

Feeding observations from field notes and lab dissections were entered into a computer data base and then extracted via various cross indices to establish predator-prey relationships.

In data tables in this report, absence of a species is indicated by 0 and observations for a species is indicated by dash (-).

VI. RESULTS

A. KACHEMAK BAY - ROCK SUBSTRATE

1. The Biological Assemblage at Archimandritof Shoals

Since 1975, numerous sites have been examined on Archimandritof Shoals. Three additional sites were examined in 1978 (Table 1, Appendices A-1 to A-3). Algal cover was generally light and patchy at the shallow sites and very sparse at the deeper sites. The major alga at shallower depths was *Agarum*; its density and cover averaged 2.0/m^2 and 8.8 percent at a depth of 4.6 m. Cover by encrusting coralline algae averaged 42.5 percent. At 6.7 m, density of *Agarum* decreased to 0.5/m^2. An ephemeral bed of *Laminaria* and *Nereocystis* was also present at this depth, but densities only averaged 0.6 and 0.4/m^2 respectively. At 15.5 m, the only algal taxa noted (encrusting coralline and *Rhodymenia palmata*) were sparse. A total of 10 herbivore species was reported from these sites.

The primary grazer was the sea urchin *Strongylocentrotus*, averaging 47.0/m^2 at 4.6 m and 137/m^2 at 6.7 m. None was observed at 15.5 m. From 1977 data, the populations were composed mainly of adult animals with a mean diameter of 40.0 mm. Size distribution was unimodal, suggesting that recruitment to the population was slow (Lees and Houghton 1977). Less important grazers were *Tonicella* and *Schizoplax* with 21.0 and 3.0/m^2 at 4.6 m.

Among the more than forty species of suspension feeders reported from this site, the most important were the clams *Modiolus* and *Saxidomus*, and the sabellid polychaete *Potamilla*. Non-destructive quadrat counts of *Modiolus* taken at 4.6, 6.7 and 15.5 m depths produce density estimates of 18.0, 63.2 and 134.4 individuals/m^2, respectively. These are probably quite conservative since a comparison of pre- and post-removal counts showed that the actual density is two to three times that indicated by visual estimates. *Potamilla* coverage averaged 52.5 percent at the 6.7 m site and was frequently found growing densely around *Modiolus*. Also in association

TABLE 1 SPECIES COMPOSITION FOR ARCHIMANDRITOF SHOALS; 28 JUNE 1978

TAXA		Depth below MLLW (m)				
		4.6	6.7	6.7	6.7	6.7
ALGAE - Phaeophyta						
Agarum cribrosum, adult	($\bar{x}$ ± s,%)	8.8 ± 6.3%	-	-	-	-
	($\bar{x}$ ± s)	0.5 ± 0.6	0.3 ± 0.5	-	-	-
	(no./m^2)	2.0	0.1	-	-	-
A. cribrosum, juvenile	($\bar{x}$ ± s)	-	2.2 ± 0.8	-	-	-
	(no./m^2)	-	0.4	-	-	-
Laminaria groenlandica, juvenile	($\bar{x}$ ± s)	0	3.2 ± 2.5	-	-	-
	(no./m^2)	0	0.6	-	-	-
Nereocystis luetkeana, juvenile	($\bar{x}$ ± s)	0	2.0 ± 1.8	-	-	-
	(no./m^2)	0	0.4	-	-	-
ALGAE Rhodophyta						
Coralline alga, encrust.	($\bar{x}$ ± s,%)	42.5 ± 12.6%	-	-	-	-
CNIDARIA - Hydrozoa						
Abietinaria spp	($\bar{x}$ ± s,%)	2.1 ± 2.3%	-	-	-	-
ANNELIDA - Polychaeta						
Potamilla ?reniformis	($\bar{x}$ ± s,%)	52.5 ± 13.2%	-	-	-	-
MOLLUSCA - Gastropoda						
Fusitriton oregonensis	($\bar{x}$ ± s)	0	2.0 ± 2.9	-	-	-
	(no./m^2)	0	0.4	-	-	-
Neptunea lyrata	($\bar{x}$ ± s)	0	1.0 ± 1.5	-	-	-
	(no./m^2)	0	0.2	-	-	-
Trichotropis cancellata	($\bar{x}$ ± s)	0.3 ± 0.5	-	-	-	-
	(no./m^2)	1.0	-	-	-	-
MOLLUSCA - Pelecypoda						
Modiolus modiolus	($\bar{x}$ ± s)	4.2 ± 2.5	-	-	-	15.8 ± 6.2
	(no./m^2)	18.0	-	-	-	63.2

TABLE 1 (Continued)

TAXA		Depth below MLLW (m)				
		4.6	6.7	6.7	6.7	6.7
Saxidomus giganteus	($\bar{x} \pm s$)	5.8 ± 3.3	-	-	-	-
	(no./m^2)	23.0	-	-	-	-
MOLLUSCA - Polyplacophora						
Schizoplax brandtii	($\bar{x} \pm s$)	0.8 ± 1.0	-	-	-	-
	(no./m^2)	3.0	-	-	-	-
Tonicella lineata	($\bar{x} \pm s$)	5.3 ± 4.8	-	-	-	-
	(no./m^2)	21.0	-	-	-	-
ECHINODERMATA - Asteroidea						
Crossaster papposus	($\bar{x} \pm s$)	0	0.3 ± 0.5	-	-	-
	(no./m^2)	0	0.1	-	-	-
Leptasterias ?hylodes	($\bar{x} \pm s$)	0	0.2 ± 0.4	-	-	-
	(no./m^2)	0	0.03	-	-	-
L. polaris acervata	($\bar{x} \pm s$)	0.3 ± 0.5	0.2 ± 0.4	-	-	-
	(no./m^2)	1.0	0.03	-	-	-
Solaster stimpsoni	($\bar{x} \pm s$)	0	0.2 ± 0.4	-	-	-
	(no./m^2)	0	0.03	-	-	-
ECHINODERMATA - Echinoidea						
Strongylocentrotus drobachiensis	($\bar{x} \pm s$)	11.8 ± 1.3	-	-	34.2 ± 6.2	-
	(no./m^2)	47.0	-	-	13.7	-
CHORDATA						
Cottidae, unid.	(no./m^2)	0	-	0.03	-	-
Lepidopsetta bilineata	(no./m^2)	0	-	0.03	-	-
Quadrat Size (m):		½ x ½	1 x 5	1 x 30	0.5 x 5	½ x ½
No. of Quadrats:		4	6	1	6	10

with Modiolus were the clams Saxidomus giganteus and Macoma inquinata. These species were found below the surface mat of Modiolus. Adult Saxidomus densities in excess of 20/m^2 were observed at a depth of 4.6 m.

Average shell length for Modiolus removed from the 6.7 m site was 8.14 cm whereas from the 15.5 m site, it was 9.03 cm. At the deeper site, the size distribution of Modiolus was unimodal with a peak near 100 mm. Very few juveniles were obtained. Using the length vs. wet tissue weight relationship obtained from the deeper site, biomass at that location averaged 3238.0 g wet tissue/m^2.

Several additional species of suspension feeders extend above the substrate surface into the water column. Important among this group are hydroids, particularly of the family Sertulariidae, bryozoans such as Flustrella gigantea and the tunicate Halocynthia aurantium.

Thirty-five species of scavengers and predators were observed, including crustaceans, gastropods, starfish and fish. Overall densities were low; the snails Fusitrition oregonensis and Neptunea pribiloffensis were most numerous. At the 6.7 m depth, their densitites averaged 0.4 and 0.2/m^2 respectively. The several starfish species recorded were sparse ($<$ 0.1 individuals/m^2).

2. The Biological Assemblage at Bishop's Beach

Three sites were surveyed off Bishop's Beach; all were deeper than 14 m. The area was quite silty with patches of cobble, small boulders and mud. No brown algae were observed; however, the foliose rhodophytes Opuntiella and Rhodymenia pertusae were noted.

At the three depths surveyed (14.6, 15.2 and 18.3 m) suspension feeders dominated the assemblage (Table 2). Species composition was very similar to that reported for Archimandritof Shoals. Sertulariid hydroids, sponges, the mussel Modiolus and Balanus were the most important species.

TABLE 2

SPECIES COMPOSITION FOR BISHOP'S BEACH SUBTIDAL ZONE; 1/4 m^2 SQUARE QUADRATS

Taxa	Date Depth (m)	9/26/78 18.3	10/6/78		11/25/78 15.2
			15.2	16.0	
PORIFERA					
?*Halichondria* sp.	$\bar{x} \pm s$ %	0.9 ± 1.8 %	4.1 ± .6.5 %	0.8 ± 1.6 %	
CNIDARIA - Hydrozoa					
Abietinaria sp.	$\bar{x} \pm s$ %	0.2 ± 0.6 %	0.4 ± 1.3 %		0.6 ± 1.4 %
Campanularia verticillata	$x \pm s$ %	1.1 ± 2.1 %	0.2 ± 0.6 %		
Sertulariidae,unid	$x \pm s$ %	0.6 ± 1.4 %	1.6 ± 2.6 %	2.2 ± 2.5 %	2.0 ± 2.1 %
ARTHROPODA - Crustacea					
Balanus spp.	$\bar{x} \pm s$	8.8 ± 4.9 %	0.6 ± 0.9 %	10.0 ± 4.1 %	0.1 ± 0.5 %
Caridea, unid	no/m^2	P	P	P	P
Elassochirus gilli	no/m^2		0.3	1.6	
Oregonia gracilis	no/m^2	0.9	0.6	2.8	0.9
Pagurus sp.	no/m^2	4.0	1.7	10.8	P
MOLLUSCA - Gastropoda					
Acmaea mitra	no/m^2		6.3	0.4	4.3
Fusitriton oregonensis	no/m^2	1.4	0.6	3.6	1.1
Neptunea spp.	no/m^2	2.0	0.9	1.2	0.9
Nucella lamellosa	no/m^2			28.4	
Trophon sp.	no/m^2	1.1		0.8	0.6
MOLLUSCA - Pelecypoda					
Chlamys spp.	no/m^2	2.0		1.6	
Modiolus modiolus	no/m^2	39.4	9.1	26.4	18.0
Pododesmus macroschisma	no/m^2	2.9	1.4		
MOLLUSCA - Polyplacophora					
Tonicella sp.	no/m^2	1.1	10.3	2.8	
ECTOPROCTA					
Flustrella gigantea	$\bar{x} \pm s$ %	0.3 ± 0.7 %	1.0 ± 2.7 %	1.4 ± 2.1 %	0.8 ± 1.5 %
Microporina borealis	$x \pm s$ %				1.4 ± 1.6 %
BRACHIOPODA					
Terebratalia transversa	no/m^2	2.0	0.6		
ECHINODERMATA - Echinoidea					
Strongylocentrotus drobachiensis	no/m^2		4.3		2.9
Number of Quadrats:					
Uncorrected depth (ft.)		60	50	60	50
(m)		18.3	15.2	18.3	15.2
Substrate:		Cobbles, rocks, shell debris, and small boulders	Cobble, shell debris, (*Modiolus* bed) and small rocks	Cobble, small rocks, shell debris, (*Modiolus* bed)	Cobble, shell debris, (*Modiolus* bed and, small rocks)

In August 1976, density of Modiolus at 14.6 m was estimated to be $15/m^2$ with wet tissue biomass of approximately 710 g/m^2 (Rosenthal and Lees 1976). Non-destructive quadrat counts of Modiolus at the deeper stations in 1978 produced mean density estimates of 9.1 and $18.0/m^2$ at 15.2 m and 39.4 and $26.4/m^2$ at 18.3 m. As noted above, however, surface counts tend to yield conservative estimates. The major herbivorous species were the urchin Strongylocentrotus, the chiton Tonicella, and the limpet Acmaea mitra; density estimates for Strongylocentrotus were 2.9 and $4.3/m^2$ at 15.2 m. Size data from 1976 showed a unimodal distribution with an average test diameter of 51.4 mm (Rosenthal and Lees 1976); the paucity of specimens below 40 mm was considered peculiar. Both Tonicella and Acmaea were more abundant in the shallower depths.

The snails Neptunea and Fusitriton, hermit crabs, and the crab Oregonia gracilis were numerically the dominant predator/scavengers; their densities were slightly higher at the deepest station. Several other predators observed were Placiphorella, Pteraster, Nucella, Elassochirus and a few fish species.

3. The Biological Assemblage at Bluff Point

The Bluff Point subtidal region is generally a fairly flat area dominated by patches of cobble, larger boulders, and shell debris. Reef structures and pavement bedrock are less common. The area is swept by moderate currents and the water is usually somewhat less turbid than at Archimandritof Shoals and Bishop's Beach (Figure 1).

A number of sites have been examined in this area (Rosenthal and Lees 1976, Lees and Houghton 1977). Two additional dives were made in 1978 (Table 3; Appendices B-1 and B-2). The description of the assemblage is based on combined data.

Significant plant production appears to be restricted to rocky substrate shallower than 15 m below MLLW. In previous years, several large beds of Alaria were visible along the coastline. They have been reduced and patchy since 1975. At 15 m the dominant algae were Agarum, with up to 27

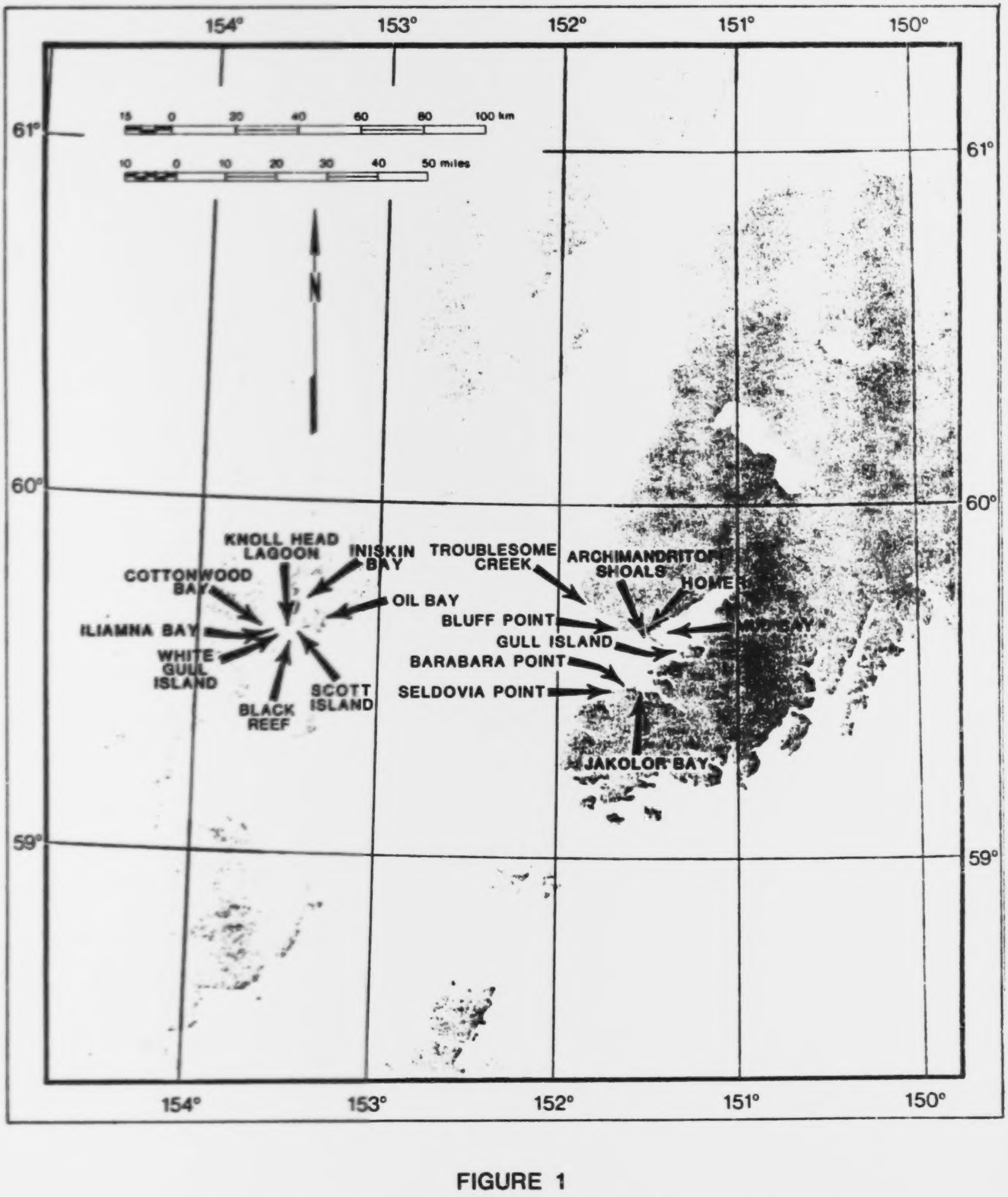
154°
153°
152°
151°
150°
61°
60°
59°
15 0 20 40 60 80 100 km
10 0 10 20 30 40 50 miles
N
KNOLL HEAD LAGOON
INISKIN BAY
COTTONWOOD BAY
OIL BAY
ILIAMNA BAY
WHITE GULL ISLAND
BLACK REEF
SCOTT ISLAND
TROUBLESOME CREEK
ARCHIMANDRITOFF SHOALS
HOMER
BLUFF POINT
MUD BAY
GULL ISLAND
BARABARA POINT
SELDOVIA POINT
JAKOLOF BAY

FIGURE 1

STUDY AREAS FOR LITTORAL STUDIES IN LOWER COOK INLET

TABLE 3 RECONNAISSANCE SURVEY FROM BLUFF POINT SUBTIDAL AREA; 31 JULY 1978

TAXA	Depth (m)*	
	15.6	10.1-11.8
ALGAE - Phaeophyta		
Agarum cribrosum		X
ALGAE - Rhodophyta		
Kallymenia sp		X
PORIFERA		
Halichondria panicea		X
CNIDARIA - Hydrozoa		
Hydrozoa, unid.		X
ANNELIDA - Polychaeta		
Owenia fusiformis		X
ARTHROPODA - Crustacea		
Balanus sp	X	
Cancer oregonensis		X
Elassochirus gilli	X	X
Pagurus sp		X
MOLLUSCA - Gastropoda		
Archidoris odneri		X
Cadlina sp	X	
Coryphella sp		X
Dendronotus dalli	X	X
Fusitriton oregonensis	X	X
Neptunea lyrata		X
Nudibranch, Dorid, unid.	X	
MOLLUSCA - Pelecypoda		
Chlamys sp	X	
Entodesmus saxicola		X
Modiolus modiolus		X
Pododesmus macroschisma	X	X
Serripes shell		X
MOLLUSCA - Polyplacophora		
Cryptochiton stelleri	X	X
Placiphorella sp	X	X
ECTOPROCTA		
Alcyonidium pedunculatum		X
Flustrella gigantea	X	X
Microporina borealis		X
BRACHIOPODA		
Hemithiris psittacea	X	
Terebratalia transversa	X	
ECHINODERMATA - Asteroidea		
Crossaster papposus	X	X
Evasterias troschelii		X
Henricia sanguinolenta	X	X
Leptasterias pularis		X
Pteraster tesselatus	X	X
Solaster dawsoni		X
Tosiaster arcticus		X
ECHINODERMATA - Echinoidea		
Strongylocentrotus drobachiensis	X	X
ECHINODERMATA - Holothuroidea		
Cucumaria fallax		X
Eupentacta quinquesemita		X
Psolus chitonoides	X	
CHORDATA - Tunicata		
Distaplia occidentalis		X
Halocynthia aurantium	X	X
Ritterella ?pulchra		X
Styela montereyensis		X
CHORDATA - Pisces		
Bathymasteridae, unid.		X
Hemilepidotus jordani		X
Myoxocephalus polyacanthocephalus		X
Sebastes sp		X

Substrate: Large boulders with cobble, rock and bedrock plants/m^2 and 45 percent cover, Laminaria, with at least 13/m^2, and encrusting coralline algae with up to 75 percent cover. Other significant algae included Desmarestia, Callophyllis, Hildenbrandia, and Ptilota (Appendix B; Rosenthal and Lees 1976).

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*Below MLLW

Among the herbivores, Strongylocentrotus, Acmaea mitra, Tonicella, and Cryptochiton were most numerous. Estimates of Strongylocentrotus densities averaged 5/m^2 in 1976. Density estimates from recent surveys were 7.4/m^2 and 0.2/m^2 at 10.1 and 20 m depths, respectively. Size structure of the urchin population were basically unimodal in earlier studies; the average test diameter of 44.5 mm indicated an adult population. Again, juveniles were absent.

The urchins displayed foraging behavior similar to those at Archimandritof Shoals. Rather than being cryptic and sedentary, individuals were exposed and probably mobile, suggesting a relative undersupply of drift algae. Such behavior is predictable at both locations in view of the scarcity of algae and effective sea urchin predators such as the sun star Pycnopodia and sea otters (Lees and Houghton 1977).

Subdominant grazers included the limpets Acmaea mitra and Diodora aspera, the snails Calliostoma and Lacuna, and chitons Tonicella and Cryptochiton. These species probably have a significant impact on the abundance of macrophytes at shallower depths. At the 10.1 m site, densities for Tonicella and Acmaea averaged 8.0 and 1.1/m^2, respectively.

Over 60 species of suspension feeders were observed in the area. The mussel Modiolus and the large fleshy, shrubby bryozoan Flustrella gigantea were visibly the most important. From earlier surveys, Modiolus densities of up to 57/m^2 were reported, but the average was estimated to be closer to 15/m^2. From the 1978 survey 3 divers at 20 m at the same general locale reported Modiolus densities ranging from 0 to 96/m^2 while estimates of fresh tissue weight ranged up to 6752.8 g/m^{2}The density estimate at 10.1 m was 8 indiv/m^2 (based on visual counts). Size structure for Modiolus at

Bluff Point consistently has been strongly unimodal. In earlier studies, average shell length was 12.6 cm (Rosenthal and Lees 1976) and in the recent studies, 12.2 cm; juveniles were absent.

The bryozoan *Flustrella* was previously recorded occurring in densities of up to 28 colonies/m^2 and 30 percent cover (Rosenthal and Lees 1976). In the recent survey at 10.1 m depth, cover average 7.9 percent. Colony heights of 15 cm were recorded. Other important suspension feeders included the bryozoan *Microporina borealis* with 2.7 percent average cover, the hydroids *Abietinaria* and *Campanularia*, with 2.9 and 1.3 percent cover, sabellid worms with 2.4 percent cover, and the rock jingle *Pododesmus macroschisma*.

About 50 predator/scavenger species were observed in the area. Numerically, the most important species were *Fusitriton*, averaging 1.1 and 1.4/m^2 at the 10.1 and 19.5 m sites, respectively, and *Neptunea*. Starfish and crustaceans were particularly diverse and important groups of predators. Of the ten species of starfish observed, five, including *Crossaster papposus*, *Evasterias*, *Lethasterias nanimensis*, *Pteraster tesselatus* and *Solaster dawsoni*, were common. Of the thirteen species of crustaceans observed, eight were common. Particularly notable were the crabs *Hyas lyratus* and *Oregonia gracilis* and the hermit crabs *Elassochirus gilli*, *E. tenuimanus*, *Pagurus trigonocheirus* and *P. ochotensis*. Also, one-year old king crab (carapace width <1 cm) were common at the deeper sites.

In some areas, densities and diversities of predators/scavengers were exceptionally high. At 19.5 m, a large proportion of the species observed were predators or scavengers, and most were large and common. For example, the slender star, *Evasterias* averaged 1.4 individuals/m^2 with a mean radius of 289 mm. Most of the predators activity in this area revolved around the predatory activities of that star on *Modiolus*; several large snails, crabs and hermit crabs were observed crowding around feeding *Evasterias* to pick off tidbits (Rosenthal and Lees 1976).

4. The Biological Assemblage at Anchor Point - Troublesome Creek

The Troublesome Creek area is very similar in physical relief to the previously described Bluff Point region. Large boulders, cobble and shell debris dominate the region, presenting a complex variety of niches. The water is sometimes less turbid than that found at Bluff Point due to dilution of turbid bay water with clean oceanic water(Figure 1).

This region had high species diversity. The dominant species at each station varied widely (Appendices C-1 through C-8). Macrophyte abundance and cover was low (Table 4), suggesting primary productivity was not high. In 1976, only four species of algae were reported; Agarum was the only important laminarian. In 1978, Agarum averaged only 0.4 individuals/m^2. Also present were Laminaria, Desmarestia aculeata and D. ligulata at densities of 0.2, 0.2 and 0.1 plants/m^2 respectively. Encrusting coralline algae provided 58.3 percent relative cover. The area supports a broad suite of consumers, implying high secondary productivity. Most of the consumers were long-lived species with populations of mature individuals. We postulate that plant production was reduced due to the intense competition for available substrate between plants and encrusting animals.

Suspension feeders dominated the assemblage. The most abundant species was the sea cucumber, Cucumaria miniata, averaging 16.7 individuals/m^2. Relative cover of the bottom by its tentacles averaged 34 percent. Various hydroid and bryozoan species were also common, including several hydroids of the family Sertulariidae, and the bryozoan Flustrella gigantea; the latter averaged 6 percent relative cover. The tunicates Distalplia sp. and Ritterella pulchra and the sponge Halichondria panicea also covered significant portions of bottom. Other important suspension feeders were the butter-clam Saxidomus gigantea and the large barnacle Balanus nubilus at a depth of 8 m.

Modiolus was founded in 1976 at 14.6 m and 20 m depths. At 14.6 m, the shell-length distribution was bimodal with a mean of 97 mm. Based on an estimated average density of 10 individuals/m^2 and the length-weight

TABLE 4 SPECIES COMPOSITION FOR TROUBLESOME CREED SUBTIDAL AREA, 8.0 M BELOW MLLW; 1 AUGUST 1978

TAXA										Cummulative Data (no./m^2)	Cummulative Data (%/m^2)
ALGAE - Chlorophyta											
Codium ritteri	($\bar{x}$ ± s,%)	0	0	0	0	0	0	0.8 ± 1.7%	0		0.5%
ALGAE - Phaeophyta											
Agarum cribrosum	($\bar{x}$ ± s,%)	-		-	-	-	-	1.7 ± 5.0%	2.0 ± 2.4%		1.8%
	($\bar{x}$ ± s)	0	1.2 ± 1.2	0.4 ± 0.5	1.0 ± 1.2	-	-	0.2 ± 0.7	1.0 ± 1.3		
	(no./m^2)	0	0.5	0.2	0.4	-	-	0.9	4.0	0.4	
Desmarestia aculeata	($\bar{x}$ ± s)	0	0	1.2 ± 2.2	0.8 ± 1.8	-	-	0	0		
	(no./m^2)	0	0	0.5	0.3	-	-	0	0	0.2	
D. ligulata	($\bar{x}$ ± s)	0	0	0.4 ± 0.9	0.2 ± 0.4	-	-	0	0		
	(no./m^2)	0	0	0.2	0.1	-	-	0	0	0.1	
Laminaria groenlandica	($\bar{x}$ ± s)	1.2 ± 2.9	0	0.4 ± 0.9	0	-	-	0	0		
	(no./m^2)	0.5	0	0.2	0	-	-	0	0	0.2	
ALGAE - Rhodophyta											
Coralline alga, encrust.	($\bar{x}$ ± s,%)	-	-	-	-	-	-	61.1 ± 25.6%	54.0 ± 15.2%		58.3%
PORIFERA											
Halichondria panicea	($\bar{x}$ ± s,%)	0	0	0	0	0	7.0 ± 22.1%	0	0		2.1%
Mycale ?lingua	($\bar{x}$ ± s,%)	-	-	-	-	2.2 ± 6.7%	0	0	0		0.6%
Porifera, unid.	($\bar{x}$ ± s,%)	-	-	-	-	1.1 ± 3.3%	0	0	0		0.3%
CNIDARIA - Hydrozoa											
Abietinaria sp.	($\bar{x}$ ± s,%)	-	-	-	-	-	0	1.1 ± 3.3%	0		0.4%
Hydrozoa, unid.	($\bar{x}$ ± s,%)	-	-	-	-	2.8 ± 4.4%	0	0	0		0.7%
	($\bar{x}$ ± s)	-	-	-	-	2.4 ± 3.8	0	0	0		
	(no./m^2)	-	-	-	-	9.8	0	0	0	2.6	
Sertularella reticulata	($\bar{x}$ ± s,%)	-	-	-	-	0	0	3.6 ± 3.4%	0		1.0%
Sertulariidae, unid.	($\bar{x}$ ± s,%)	-	-	-	-	-	-	-	7.8 ± 4.6%		

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TABLE 4 (Continued)

TAXA										Cumulative Data (no./m^2)	(%/m^2)
CNIDARIA - Anthozoa											
Anthozoa, unid.	($\bar{x}$ ± s)	0	0	1.8 ± 2.2	2.3 ± 1.7	0	0	0	0.3 ± 0.8		
	(no./m^2)	0	0	0.7	0.9	0	0	0	1.3	0.3	
Cribrinopsis sp	($\bar{x}$ ± s)	-	-	-	-	0	0.1 ± 0.3	0.7 ± 1.3	0		
	(no./m^2)	-	-	-	-	0	0.4	2.7	0	0.8	
Metridium senile	($\bar{x}$ ± s)	0	0	0	0	0	1.0 ± 3.2	0	3.2 ± 2.5		
	(no./m^2)	0	0	0	0	0	4.0	0	12.7	0.5	
Tealia crassicornis	($\bar{x}$ ± s)	0	0	0.4 ± 0.9	2.2 ± 0.4	0	0	0	0.3 ± 0.5		
	(no./m^2)	0	0	0.2	0.9	0	0	0	1.3	0.2	
ARTHROPODA - Crustacea											
Balanus nubilus	($\bar{x}$ ± s,%)	-	-	-	-	0	0	0.3 ± 0.7%	0		0.1%
	($\bar{x}$ ± s)	-	-	-	-	0	0	0.8 ± 2.0	0		
	(no./m^2)	-	-	-	-	0	0	3.1	0	0.8	
Balanus sp	($\bar{x}$ ± s)	-	-	-	-	0	0.2 ± 0.6	0	0		
	(no./m^2)	-	-	-	-	0	0.8	0	0	0.2	
Cancer oregonensis	($\bar{x}$ ± s)	-	-	-	-	0	0	0.9 ± 1.4	0		
	(no./m^2)	-	-	-	-	0	0	3.6	0	0.9	
Elassochirus gilli	($\bar{x}$ ± s)	0	0	0.6 ± 0.9	0.6 ± 0.9	0	0	0.7 ± 0.9	0.3 ± 0.5		
	(no./m^2)	0	0	0.2	0.2	0	0	2.7	1.3	0.2	
Oregonia gracilis	($\bar{x}$ ± s)	-	-	-	-	0	0	0.9 ± 1.4	0		
	(no./m^2)	-	-	-	-	0	0	3.6	0	0.9	
Paguridae, unid.	($\bar{x}$ ± s)	-	-	-	-	0	0	P*	2.7 ± 2.9		
	(no./m^2)	-	-	-	-	0	0	-	10.7	2.6	
Pugettia gracilis	($\bar{x}$ ± s)	-	-	-	-	0	0	0	0.8 ± 1.0		
	(no./m^2)	-	-	-	-	0	0	0	3.3	0.6	
MOLLUSCA - Cephalopoda											
Octopus dofleini	($\bar{x}$ ± s)	0	0	0.2 ± 0.4	0	0	0	0	0		
	(no./m^2)	0	0	0.1	0	0	0	0	0	0.02	
MOLLUSCA - Gastropoda											
Acmaea mitra	($\bar{x}$ ± s)	-	-	-	-	0	0	0.4 ± 0.9	2.7 ± 1.2		
	(no./m^2)	-	-	-	-	0	0	1.8	10.7	2.4	

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TABLE 4 (Continued)

TAXA										Cumulative Data (no./m^2) (%/m^2)
Acmaeidae, unid.	($\bar{x}$ ± s)	-	-	-	-	0	0	0	0.5 ± 1.2	
	(no./m^2)	-	-	-	-	0	0	0	2.0	0.4
Amphissa columbiana	($\bar{x}$ ± s)	-	-	-	-	0	0	0	0.2 ± 0.4	
	(no./m^2)	-	-	-	-	0	0	0	0.7	0.1
Cadlina luteomarginata	($\bar{x}$ ± s)	0	0	0	0.2 ± 0.4	0	0	0	0	
	(no./m^2)	0	0	0	0.1	0	0	0	0	0.02
Calliostoma ligata	($\bar{x}$ ± s)	0	0	0	0	0	0	0	0.3 ± 0.8	
	(no./m^2)	0	0	0	0	0	0	0	1.3	0.03
Fusitriton oregonensis	($\bar{x}$ ± s)	0	0	0.4 ± 0.5	0.4 ± 0.5	0	0	0.6 ± 1.3	0.3 ± 0.5	
	(no./m^2)	0	0	0.2	0.2	0	0	2.2	1.3	0.2
Hermissenda crassicornis	($\bar{x}$ ± s)	0	0	0.6 ± 0.5	0.2 ± 0.4	0	0	0	0	
	(no./m^2)	0	0	0.2	0.1	0	0	0	0	0.1
Margarites pupillus	($\bar{x}$ ± s)	-	-	-	-	0	0	0	0.7 ± 1.6	
	(no./m^2)	-	-	-	-	0	0	0	2.7	0.5
Neptunea lyrata	($\bar{x}$ ± s)	0.2 ± 0.4	0	0.2 ± 0.4	0.2 ± 0.4	0	0.1 ± 0.3	0	0.2 ± 0.4	
	(no./m^2)	0.1	0	0.1	0.1	0	0.4	0	0.7	0.1
Nudibranch, unid., white	($\bar{x}$ ± s)	0.2 0.4	0	0	0	0	0	0	0	
	(no./m^2)	0.1	0	0	0	0	0	0	0	0.02
Trichotropis cancellata	($\bar{x}$ ± s)	-	-	-	-	0	0	0	0.2 ± 0.4	
	(no./m^2)	-	-	-	-	0	0	0	0.7	0.1
MOLLUSCA - Pelecypoda										
Mya truncata	($\bar{x}$ ± s)	-	-	-	-	0	0	0	0.2 ± 0.4	
	(no./m^2)	-	-	-	-	0	0	0	0.7	0.7
Saxidomus giganteus	($\bar{x}$ ± s)	-	-	-	-	-	-	-	7.3 ± 3.1	
	(no./m^2)	-	-	-	-	-	-	-	29.3	-
MOLLUSCA - Polyplacophora										
Cryptochiton stelleri	($\bar{x}$ ± s)	0.5 ± 0.8	0.2 ± 0.4	0.6 ± 0.5	0.4 ± 0.5	0	0	0	0.2 ± 0.4	
	(no./m^2)	0.2	0.1	0.2	0.2	0	0	0	0.7	0.2
Mopalia sp	($\bar{x}$ ± s)	0	0	0	0	0	0	0	0.3 ± 0.8	
	(no./m^2)	0	0	0	0	0	0	0	1.3	0.03

TABLE 4 (Continued)

TAXA										Cumulative Data	
										(no./m^2)	(%/m^2)
Placiphorella sp	($\bar{x}$ ± s)	0	0	0	0	0	0	0	0.2 ± 0.4		
	(no./m^2)	0	0	0	0	0	0	0	0.7	0.02	
Tonicella insignis	($\bar{x}$ ± s)	-	-	-	-	0	0	0	0.5 ± 0.2		
	(no./m^2)	-	-	-	-	0	0	0	2.0	0.4	
T. lineata	($\bar{x}$ ± s)	-	-	-	-	0	0	0	1.8 ± 1.6		
	(no./m^2)	-	-	-	-	0	0	0	7.3	1.3	
Tonicella sp	($\bar{x}$ ± s)	-	-	-	-	0	0	0.2 ± 0.7	0		
	(no./m^2)	-	-	-	-	0	0	0.9	0	0.2	
ECTOPROCTA											
Flustrella gigantea	($\bar{x}$ ± s,%)	-	-	-	-	-	-	5.8 ± 4.4%	6.3 ± 4.5%		6.0%
no. of colonies:	($\bar{x}$ ± s)	-	-	-	-	0.6 ± 0.9	0.5 ± 0.7	-	-		
	(no./m^2)	-	-	-	-	2.2	2.0	-	-	2.1	
Heteropora sp	($\bar{x}$ ± s,%)	-	-	-	-	0	0	1.4 ± 1.6%	1.2 ± 0.4%		0.6%
ECHINODERMATA - Asteroidea											
Crossaster papposus	($\bar{x}$ ± s)	0	0	0.4 ± 0.5	0.2 ± 0.4	0	0	0	0		
	(no./m^2)	0	0	0.2	0.1	0	0	0	0	0.05	
Evasterias troschelii	($\bar{x}$ ± s)	0	0	0.2 ± 0.4	0	0	0	0	0		
	(no./m^2)	0	0	0.1	0	0	0	0	0	0.02	
Henricia leviuscula	($\bar{x}$ ± s)	0	0	0	0.2 ± 0.4	0	0	0	0		
	(no./m^2)	0	0	0	0.1	0	0	0	0	0.02	
H. sanguinolenta	($\bar{x}$ ± s)	0	0	0	0.2 ± 0.4	0	0	0	0		
	(no./m^2)	0	0	0	0.1	0	0	0	0	0.02	
Henricia spp	($\bar{x}$ ± s)	0.7 ± 0.8	0.2 ± 0.4	0	0	0	0	0.2 ± 0.4	0		
	(no./m^2)	0.3	0.1	0	0	0	0	0.9	0	0.1	
Leptasterias ?hylodes	($\bar{x}$ ± s)	0	0	0.2 ± 0.4	0	0	0	0	0		
	(no./m^2)	0	0	0.1	0	0	0	0	0	0.02	
Orthasterias koehleri	($\bar{x}$ ± s)	0	0	0	0	0	0	0.1 ± 0.3	0		
	(no./m^2)	0	0	0	0	0	0	0.4	0	0.02	

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TABLE 4 (Continued)

TAXA										Cumulative Data	
										(no./m^2)	(%/m^2)
ECHINODERMATA - Echinoidea											
Strongylocentrotus	($\bar{x}$ ± s)	63.0 ± 17.7	42.5 ± 5.2	33.8 ± 9.1	45.8 ± 13.6	6.2 ± 4.2	3.1 ± 1.8	5.7 ± 3.9	9.0 ± 7.7		
drobachiensis	(no./m^2)	25.2	17.0	13.5	18.3	24.9	12.4	22.7	36.0	18.8	
ECHINODERMATA - Holothuroidea											
Cucumaria fallax	($\bar{x}$ ± s)	0	0.5 ± 0.8	0.4 ± 0.5	0.6 ± 0.9	0	0	0.1 ± 0.3	0		
	(no./m^2)	0	0.2	0.2	0.2	0	0	0.4	0	0.1	
C. miniata	($\bar{x}$ ± s,%)	-	-	-	-	-	-	-	34.0 ± 18.5%		-
	($\bar{x}$ ± s)	75.0 ± 15.6	21.0 ± 10.1	16.2 ± 6.8	47.6 ± 14.9	1.8 ± 2.4	2.2 ± 2.8	6.8 ± 7.7	11.3 ± 6.3		
	(no./m^2)	30.0	8.4	6.5	19.0	7.1	8.8	27.1	45.3	16.7	
Cucumaria sp. white	($\bar{x}$ ± s)	0	0	0	0	0	0	0.2 ± 0.7	0		
	(no./m^2)	0	0	0	0	0	0	0.9	0	0.03	
ECHINODERMATA - Ophiuroidea											
Ophiopholis sp.	(no./m^2)	-	-	-	-	0	0	P	0	-	
CHORDATA - Tunicata											
Ascidacea, unid.	($\bar{x}$ ± s)	-	-	-	-	0	0.2 ± 0.6	0	0		
	(no./m^2)	-	-	-	-	0	0.8	0	0	0.7	
Distaplia sp. colonial	($\bar{x}$ ± s)	-	-	-	-	0	1.8 ± 4.4	0	0		
	(no./m^2)	-	-	-	-	0	7.2	0	0	2.1	
Ritterella pulchra	($\bar{x}$ ± s,%)	-	-	-	-	10.0 ± 12.6%	0	7.3 ± 7.4%	3.0 ± 2.1%		5.1%
no. of colonies:	($\bar{x}$ ± s)	-	-	-	-	2.9 ± 3.8	0	-	-	-	
	(no./m^2)	-	-	-	-	11.6	0	-	-	5.5	
Tunicata, unid. compound	($\bar{x}$ ± s,%)	-	-	-	-	1.1 ± 3.3%	0	0	0		0.3%
no. of colonies:	($\bar{x}$ ± s)	-	-	-	-	0.1 ± 0.3	0	0	0		
	(no./m^2)	-	-	-	-	0.4	0	0	0	0.1	
CHORDATA											
Artedius sp.	($\bar{x}$ ± s)	0	0	0	0	0	0	0.3 ± 0.5	0		
	(no./m^2)	0	0	0	0	0	0	1.3	0	0.05	
Quadrat Size (m):		0.5 x 5	0.5 x 5	0.5 x 5	0.5 x 5	¼	¼	¼	¼		
No. of Quadrats		6	6	5	5	9	10	9	6		

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* P = Present

regression from Bluff Point, the estimated biomass of Modiolus was around 430 g of wet tissue/m^2 (Rosenthal and Lees 1976).

The most abundant animal was the sea urchin, Strongylocentrotus drobachiensis, a herbivore that averaged 18.8 individuals/m^2 at the site surveyed in 1978, it probably grazed a substantial proportion of the macrophyte standing stocks. In 1976, the size distribution for urchins at Troublesome Creek was basically unimodal; the average test diameters ranging from 37.3 mm to 47.6 mm indicate mature populations. Eight other species of herbivores were recorded from the region, but their effects were probably minor in comparison to those of the urchins.

Predators were diverse and relatively abundant. About 40 species, primarily crustaceans, starfish, gastropods, and fish, were reported from the 1976 surveys. The starfish Crossaster and Evasterias occurred at densities up to 0.03/m^2. Size of Evasterias was impressively large compared to populations commonly seen in Kachemak Bay; the average diameter was 57 cm (Rosenthal and Lees 1976). Other common predators were the hermit crab Pagurus sp. and the starfish Henricia sanguinolenta. Fish were more abundant and diverse than at other locations in Kachemak Bay. Average size of cottids and greenlings was large.

5. The Biological Assemblage at Jakolof Bay

Most observations in Jakolof Bay were confined to the shallow reef that projects off the rocky headland on the northwest side of the bay. This geologic feature blocks nearly half the entrance on most tide cycles thereby creating strong currents as the flow jets through the narrow opening.

The macrophyte assemblage was multilayered with a surface canopy floating above a vegetative understory composed of shorter algae. The ribbon kelp Alaria fistulosa dominated the shallow reef substrate from 3 to 6 m below the sea surface. This species, along with the less common bull kelp Nereocystis luetkeana, formed a dense surface canopy visible on slack tides during the spring and summer. Densities of mature *Alaria* peaked at an average of about 2 individuals/m^2 during July-August. Adult plants of *Agarum cribrosum* and *Laminaria groenlandica*, smaller plants that form the understory canopy, attain densities exceeding 20/m^2. Beneath this brown algal canopy was another layer of smaller foliose reds such as *Callophyllis*, *Kallymenia* and *Turnerella*.

In the deeper waters of the entrance channel (8-12 m), the surface canopy was absent and understory densities were somewhat reduced. However, *Laminaria* plants were still quite robust and abundant.

Suspension feeders were very abundant and exhibited high species diversity; in several places they carpeted the bottom (Table 5). Dominant species included the sabellid polychaete *Potamilla ?reniformis*, the mussel *Modiolus* and the large anemone *Metridium senile*. Some of the common forms lived buried in the cobble/shell debris matrix; these included the clams *Saxidomus giganteus*, *Humilaria kennerlyi*, and *Macoma* the sipunculids *Golfingia* and *Phascolosoma agassizii* and the echiurid *Bonelliopsis alaskanus* The northern ugly clam Entodesma *saxicola* was common nesting on the cobble and on bedrock slopes. The large barnacle *Balanus nubilus* and the large erect, orange sponge *Esperiopsis rigida* were also common in these habitats, along with the sea cucumbers *Cucumaria vegae*, various hydroids, sabellid worms and the brittlestar *Ophiopholis aculeata*.

The urchin *Strongylocentrotus drobachiensis* was the principal grazer on the reef. Densities of up to 50 individuals/m^2 were observed. Basically the size distribution were unimodal, and the large average diameter indicated that the populations were composed mainly of adults. Animals less than 12 mm were uncommon suggesting that successful recruitment was rare. Off the reef in the deeper water, densities dropped to 1.3/m^2.

The impact of urchin grazing became noticeable by summer 1977. By that time the urchins had completely grazed the macrophytes off some shallower portions of the reef and were advancing in high densities towards the deeper

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TABLE 5

SUMMARY OF MAJOR ANIMAL SPECIES FROM JAKOLOF BAY 1/4 m^2, 1978

	Reef		Channel			
	2/2/79		10/7/79		11/28/79	
	$\bar{x} \pm s$	No./m^2	$\bar{x} \pm s$	No./m^2	$\bar{x} \pm s$	No./m^2
PORIFERA						
Halichondria panicea (%)			0.4 ± 1.4		1.0 ± 2.0	
CNIDARIA - Hydrozoa						
Abietinaria spp. (%)	5.2 ± 4.8		4.9 ± 3.6		3.3 ± 3.7	
Campanularia verticillata (%)			0.4 ± 1.4		1.2 ± 1.9	
Sertulariidae (%)	2.2 ± 5.1		0.8 ± 1.9		2.5 ± 2.3	
ECHIURA						
Bonelliopsis alaskanus	-	-	0.7 ± 1.7	2.7	0.8 ± 0.9	3.0
ARTHROPODA - Crustacea						
Caridea			P		P	
Elassochirus gilli			0.3 ± 0.5	1.0	0.1 ± 0.3	0.3
Pagurus sp.	P		P		P	
MOLLUSCA - Gastropoda						
Acmaea mitra	0.2 ± 0.4	0.9	0.2 ± 0.4	0.7	0.1 ± 0.3	0.3
Calliostoma ligata	0.1 ± 0.3	0.4	0.3 ± 0.8	1.3		
Dendronotus dalli			0.2 ± 0.4	0.7	0.1 ± 0.3	0.3
Fusitriton oregonensis	1.1 ± 1.8	4.4	0.3 ± 0.5	1.0	0.6 ± 1.0	2.3
Trophon sp.			0.3 ± 0.5	1.0	0.3 ± 0.5	1.3
MOLLUSCA - Pelecypoda						
Entodesma saxicola			0.2 ± 0.6	0.7	0.3 ± 0.6	1.0
Modiolus modiolus	0.2 ± 0.7	0.9	1.6 ± 1.7	6.3	0.4 ± 0.8	1.7
MOLLUSCA - Polyplacophora						
Tonicella sp.	0.1 ± 0.3	0.4	0.8 ± 1.1	3.0		
ECTOPROCTA						
Microporina borealis (%)					0.1 ± 0.3	
ECHINODERMATA - Asterozoa						
Evasterias troschelii	0.1 ± 0.3	0.4	0.2 ± 0.4	0.7	0.4 ± 0.7	1.7
Orthasterias koehleri			0.2 ± 0.4	0.7	0.1 ± 0.3	0.3
Pycnopodia helianthoides			0.2 ± 0.4	0.7		
ECHINODERMATA - Echinoidea						
Strongylocentrotus drobachiensis	0.4 ± 0.7	1.8	0.2 ± 0.4	0.7		
ECHINODERMATA - Ophiuroidea						
Ophiopholis aculeata			P		P	
Number of Quadrats:	9		12		12	
Depth (m below MLLW)	4.3-7.2		6-8		8-9	
Substrate						

perimeter of the reef. Casual observations seemed to indicate that the urchins preferred *Alaria* over *Agarum* or *Laminaria*; however, the latter species also were consumed eventually. Several times, aggregations of urchins were observed feeding on *Cryptochiton* and *Fusitriton*.

Other important herbivores included the chitons *Cryptochiton stelleri*, *Tonicella* spp., and the snails *Calliostoma* spp. and *Margarites* spp. In the channel, density of these species averaged less than $1.0/m^2$.

Asteroids and fishes were the most common and influential predators on the reef. The most abundant sea star was *Evasterias troschelii*; its density averaged $0.2/m^2$ on the reef and $0.7/m^2$ in the entrance channel. The population generally was composed of large specimens; the largest had a diameter of 67.6 cm. The sunstar *Pycnopodia helianthoides*, also typically large, occurred at densities averaging $0.14/m^2$ on the reef and $0.7/m^2$ in the entrance channel. The leather star *Dermasterias imbricata* was most common on the reef face and around rocky outcrops that supported large concentrations of the sea anemones *Metridium senile*, one of its common food items. In these areas, densities of *Dermasterias* averaged $0.06/m^2$, and again, average size of the individuals was large.

Other common predator/scavengers included the whelk *Fusitriton oregonensis* and the hermit crabs *Elassochirus gilli* and *E. tenuimanus*. *Fusitriton* averaged about 8 individuals/m^2 on the reef and $2.6/m^2$ off the reef. Maximum densities were recorded in July when large aggregated "pods" were observed engaged in reproductive activity. Size distributions for 1975, 1976, and 1978 indicate that the population was dominated by adults (e.g., 1978; shell length averaged 50.6 ± 5.9 mm) and that recruitment was low. Size structure in the *Elassochirus gilli* population was bimodal with strong recruitment; average cheliped length was 21.7 mm. Size structure in the *E. tenuimanus* population was unimodal and skewed towards juveniles; mean cheliped length was 9.6 mm. The adult mode for *E. tenuimanus* was slightly smaller than that of *E. gilli*.

Fish were seasonally important predators; they were generally present in summer and absent during winter and spring. The most abundant species were nesting rock and kelp greenling, Hexagrammos decagrammus and H. lagocephalus, which brooded egg clutched in the area during summer and competed very strongly for territories.

6. The Biological Assemblage at Barabara Bluff

The site surveyed at Barabara Bluff was a well-developed kelp bed located at the depth of approximately 10 meters. The study site was high relief bedrock and boulders (Figure 1).

As is typical of the kelp beds along the southern shore of Kachemak Bay, the site had a multilayered macrophyte assemblage. The floating canopy was formed solely by the bull kelp Nereocystis luetkeana. The species exhibited patchy distributions; average density ranged from 0.6 to 3.6 individuals/m^2. Standing crop averaged 5438.4 g/m^2 and ranged from 0 to 20 kg/m^2 (Table 6; Appendix D-1 through D-5).

The algal understory was dominated by the kelps Agarum and Desmarestia; but their distribution was also quite patchy. Agarum, the major species, averaged 22.6 percent relative cover with 8.0 individuals/m^2; its standing crop averaged 312.8 g/m^2. Desmarestia aculeata, with 5.6 percent relative cover, averaged only 28.0 g/m^2. Laminaria groenlandica was sparse.
Beneath the phaeophytes, the filamentous rhodophyte ?Pterosiphonia provided 37.2 percent relative cover.

Abundance was not recorded for the epifauna; however, a partial species list was obtained (Appendix D-5). Suspension feeders included the polychaete Thelepus cincinnatus, bivalves Protothaca staminea and Saxidomus giganteus, bryozoans Flustrella, Heteropora and Terminoflustra, the echiurid worm Bonelliopsis alaskanus, the tunicates Distaplia occidentalis and Halocynthia aurantium and the brittle star Ophiopholis aculeata.

TABLE 6 SPECIES COMPOSITION FOR BARABARA BLUFF SUBTIDAL AREA; 13 JULY 1978. APPROXIMATELY 10.0 M BELOW MLLW

TAXA							
ALGAE - Phaeophyta							
Agarum cribrosum	$(\bar{x} \pm s\%)$	-	-	-	-	-	22.6 ± 27.7%
	$(\bar{x} \pm s)$	-	-	-	-	-	4.0 ± 4.8
	(no./m^2)	-	-	-	-	-	8.0
	$(\bar{x} \pm sg)$	-	-	-	-	-	156.4 ± 229.5
	(g/m^2)	-	-	-	-	-	312.8
Desmarestia aculeata	$(\bar{x} \pm s\%)$	-	-	-	-	-	5.6 ± 5.7%
	$(\bar{x} \pm sg)$	-	-	-	-	-	14.0 ± 21.8
	(g/m^2)	-	-	-	-	-	28.0
Laminaria groenlandica	$(\bar{x} \pm s\%)$	-	-	-	-	-	0.2 ± 0.6%
	$(\bar{x} \pm s)$	-	-	-	-	-	0.1 ± 0.3
	(no./m^2)	-	-	-	-	-	0.2
	$(\bar{x} \pm sg)$	-	-	-	-	-	0.6 ± 1.7
	(g/m^2)	-	-	-	-	-	1.2
Nereocystis luetkeana(a)*	$(\bar{x} \pm s)$	3.8 ± 3.1	9.8 ± 6.8	4.4 ± 4.2	6.0 ± 8.7	-	1.8 ± 2.6
	(no./m^2)	0.4	1.0	0.4	2.4	1.7	3.6
(j)	$(\bar{x} \pm s)$	1.8 ± 2.2	2.6 ± 1.1	2.4 ± 3.4	0	-	0
	(no./m^2)	0.2	0.3	0.2	0	-	0
	$(\bar{x} \pm sg)$	-	-	-	-	-	2719.2 ± 6454.8
	(g/m^2)						5438.4
ALGAE - Rhodophyta							
Pterosiphonia sp	$(\bar{x} \pm s\%)$	-	-	-	-	-	37.2 ± 25.4%
MOLLUSCA - Polyplacophora							
Cryptochiton stelleri	$(\bar{x} \pm s)$	-	-	-	-	-	0.1 ± 0.3
	(no./m^2)	-	-	-	-	-	0.2
ECHINODERMATA - Asteroza							
Pycnopodia helianthoides	$(\bar{x} \pm s)$	0.2 ± 0.4	0	0	-	-	0
	(no./m^2)	0.02					

TABLE 6 (Continued)

TAXA							
ECHINODERMATA - Echinoidea							
Strongylocentrotus	($\bar{x} \pm s$)	-	-	-	-	-	7.1 ± 4.2
drobachiensis	(no./m^2)	-	-	-	-	-	14.2
CHORDATA - Pisces							
Bathymaster	($\bar{x} \pm s$)	0	0	0.2 ± 0.4	-	C**	0
caerulofasciatus	(no./m^2)	0	0	0.02	-		0
Hexagrammos _decagrammus_	($\bar{x} \pm s$)	0.2 ± 0.4	0.2 ± 0.4	0.6 ± 1.3	-	C	0
	(no./m^2)	0.02	0.02	0.06	-		0
_H_. _lagocephalus_	($\bar{x} \pm s$)	0	0.2 ± 0.4	0	-	C	0
	(no./m^2)	0	0.02	0	-		0
Sebastes _melanops_	($\bar{x} \pm s$)	0	0	0	0	C	0
	(no./m^2)	0	0	0	0		0
Quadrat size (m):		2 x 25	2 x 25	2 x 25	0.5 x 30	0.5 x 30	0.5 x 1

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* (a) = adult
(j) = juvenile
** C = Common

The dominant grazer was the urchin Strongylocentrotus drobachiensis; average density was of 14.2/m^2. Other grazers included the molluscs Acmaea mitra, Tonicella lineata and T. insignis, and the red urchin S. franciscanus.

Predator/scavengers were plentiful; they included the hermit crab Elassochirus gilli, the shrimp Lebbeus grandimanus (in association with the anemone Cribrinopsis similis), the nudibranch Hermissenda crassicornis, the asteroids Crossaster papposus, Henricia sanguinolenta, Orthasterias koehleri and Pycnopodia heliathoides. Also observed were kelp and rock greenlings, the searcher Bathymaster caerulofasciatus, a wolf-eel Anarrhichthys ocellatus, and several small rockfish Sebastes spp.

B. KAMISHAK BAY.

1. The Biological Assemblage at Scott Island

The study site at Scott Island was a fairly broad bedrock shelf extending from the base of the cliff at the SW end of Scott Island into the shallow subtidal zone (Figure 1). Boulders became common on the bedrock at about 1.5 m below MLLW. The rock substrate ended abruptly at about 3 m below MLLW, where the dominant substrate became sandy gravel.

In June, 1978, Laminaria plants were of moderate size and appeared healthy. Densities ranged from 1.6 to 4.0/m^2 including juveniles (Table 7). Relative cover was estimated to average 54 percent while fresh biomass was 1040.6 g/m^2. Also present were Agarum, Desmarestia, and four species of rhodophytes (Appendices E-1).

The channel on the southwest end of Scott Island has a flat current-swept, sandy gravel bottom with scattered cobble and boulders up to 2 m in diameter approximately 6 m deep. High turbidity was common. Laminaria and Agarum were scattered along a transect; densities averaged 0.6 and 0.3/m^2, respectively. Macrophytes attached to a small rock or shell were being swept along by the currents (Appendix E-2).

TABLE 7 SPECIES COMPOSITION FOR SCOTT ISLAND SUBTIDAL AREA; 15 JUNE 1978, 2 M BELOW MLLW

TAXA				
ALGAE - Phaeophyta				
Agarum cribrosum	($\bar{x}$ ± s,%)	-	0	1.5 ± 4.7%
Desmarestia aculeata	($\bar{x}$ ± s)	-	0.6 ± 0.9	-
	(no./m^2)	-	0.2	-
Laminaria groenlandica				
adults	($\bar{x}$ ± s)	7.3 ± 5.9	10.0 ± 14.8	-
	(no./m^2)	2.9	4.0	-
juveniles	($\bar{x}$ ± s)	2.0 ± 1.0	-	-
	(no./m^2)	0.8	-	-
L. saccharina	($\bar{x}$ ± s,%)	-	-	54.0 ± 35.0%
	($\bar{x}$ ± s)	-	1.0 ± 1.4	4.0 ± 5.4
	(no./m^2)	-	0.4	16.0
	($\bar{x}$ ± s,g)	-	-	650.4 ± 694.6
	(g/m^2)	-	-	2601.5
ALGAE - Rhodophyta				
Callophyllis sp	($\bar{x}$ ± s)	-	0.8 ± 1.1	-
	(no./m^2)	-	0.3	-
Constantinea sp	($\bar{x}$ ± s)	-	0.2 ± 0.4	-
	(no./m^2)	-	0.1	-
Opuntiella californica	($\bar{x}$ ± s)	-	0.8 ± 1.3	-
	(no./m^2)	-	0.3	-
Rhodymenia palmata	($\bar{x}$ ± s)	-	3.8 ± 4.1	-
	(no./m^2)	-	1.5	-
Quadrat Size (m^2):		0.5 x 5	0.5 x 5	¼
No. of Quadrats:		3	5	10

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Epifaunal animals were sparse and mosty clustered around larger cobble. Among the suspension feeders, some species of bryozoans, the hydroid Abietinaria, two sabellid polychaetes and an unidentified tunicate were important. Also present were the predatory snails Neptunea lyrata and Fusitriton, and the asteroids Leptasterias spp. and Henricia sanguinolenta (Table 8).

On a isolated large boulder in the channel, Agarum and Laminaria adults and several rhodophytes were present. Important epifaunal forms included the spong Mycale lingua, the hydroid Abietinaria gigantea, Balanus rostratus, Fusitriton (spawning), and large Strongylocentrotus drobachiensis. Also recorded were the greenlings, Hexagrammos stelleri and H. octogrammus. The latter individual was guarding an egg clutch in the Abientinaria colony.

An area observed during a reconnaissance survey in the channel on the northeast end of the island was very similar in appearance to the southwest end of the island (Appendix E-3).

2. The Biological Assemblage at Knoll Head Lagoon

The study site at Knoll Head Lagoon was a narrow rocky beach extending into the subtidal zone. Boulders became common on the bedrock at a depth of about 3 m, and the rock beach was replaced by a fine gravel/shell debris substrate with ripple marks at 7 m (Figure 1).

During the reconnaissance dive on 11 June, it was noted that the assemblage varied from 100 percent cover by various algal species at the shallow depths to no algae and heaby cover by suspension feeders and grazers at deeper levels (Appendix F-1).

In the shallow macrophyte zone, eight species of algae were common. The kelps Laminaria and Alaria praelonga were the dominant forms. In August, these two species averaged 31.7 and 62.5 percent relative cover and 13.6 and 17.2 individuals/m^2, respectively, at +0.3 to -0.6 m depths (Table 9).

TABLE 8 RECONNAISSANCE SURVEY FROM SCOTT ISLAND, SOUTH WEST END; 4 AUGUST 1978, APPROXIMATELY 6 M BELOW MLLW

TAXA	Substrate		
	SG[a]	B[b]	R[c]
ALGAE - Phaeophyta			
Agarum cribrosum		X	
Laminaria groenlandica	X	X	
ALGAE - Rhodophyta			
Constantinea subulifera	X	X	
Coralline alga, encrust.	X	X	
Odonthalia lyalli	X	X	
Rhodymenia pertusae	X	X	
PORIFERA			
Mycale ?*lingua*		X	
CNIDARIA - Hydrozoa			
Abietinaria thujarioides		X	
A. turgida		X	
Calycella syringa	X		
Campanularia urceolata		X	
Sertularia cupressoides	X		
Thuiaria cylindrica		X	
CNIDARIA - Anthozoa			
Cribrinopsis similis		X	
Metridium senile, Juv.		X	
ANNELIDA - Polychaeta			
Laonome kroyeri	X		
Pseudopotamilla sp	X		
Syllidae, unid.	X		
ARTHROPODA - Crustacea			
Achelia chelata		X	
Balanus rostratus		X	
Elassochirus gilli		X	
Pagurus beringanus		X	
MOLLUSCA - Gastropoda			
Fusitriton oregonensis		X	
Neptunea lyrata	X		
MOLLUSCA - Polyplacophora			
Mopalia sp		X	
Tonicella lineata		X	
ECTOPROCTA			
Alcyonidium polyoum	X		
Carbasea carbasea	X		
Caulibugula sp	X		
Eucratea loricata	X		
Flustrella corniculata	X		
Hippothoa hyalina	X		
Rhynchozoon bispinosum		X	
Terminoflustra membranaceo - truncata	X		
ECHINODERMATA - Asteroidea			
Henricia sanguinolenta		X	
H. tumida		X	
Leptasterias polaris acervata	X	X	
L. polaris katharinae	X		
Solaster stimpsoni	X		
ECHINODERMATA - Echinoidea			
Strongylocentrotus drobachiensis		X	
ECHINODERMATA - Holothuroidea			
Eupentacta quinquesemita		X	
CHORDATA - Tunicata			
Pelonaia corrugata	X		
CHORDATA - Pisces			
Hexagrammos ?*octogrammus*		X	
H. stelleri		X	X

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[a] SG = Sand and gravel

[b] B = Boulders

[c] R = Intertidal rock shelf

TABLE 9

SPECIES COMPOSITION OF KNOLL HEAD LAGOON STUDY AREA, AUGUST 1978

Dominant Taxa	Depth (m)		
	+0.3 to -0.6	-1.8	-3.6 to -4.8
ALGAE - Phaeophyta			
Agarum cribrosum - no/m^2	0	0.05	1.4
% cover	0	-	0.5 ± 1.6
g/m^2	0	-	15.9
Alaria praelonga - no/m^2	17.2	0.8	0
% cover	62.5 ± 30.3	33.8 ± 12.5	0
g/m^2	2044.8	-	0
Desmarestia aculeata - no/m^2	0	0.05	-
Laminaria groenlandica - no/m^2	13.6	4.7	0.1
% cover	31.7 ± 36.6	32.5 ± 8.7	-
g/m^2	2209.8	-	-
ALGAE - Rhodophyta			
Constantinea subulifera - % cover	-	4.8 ± 1.3	0
Corallina sp. - % cover	-	0.7 ± 0.6	0
encrusting coralline algae - % cover	-	62.5 ± 9.6	0
Hildenbrandia sp. - % cover	-	P	0
Odonthalia lyalli - % cover	-	13.3 ± 11.4	2.0 ± 4.7
Tokidadendron bullata - % cover	-	10.0 ± 5.8	0
CNIDARIA - no/m^2			
Anthopleura artemisia - no/m^2	0	8.0	0
Cribrinopsis similis/Tealia crassicornis	0.2	0	0.02
ARTHROPODA - no/m^2			
Pagurus hirsutiusculus	-	5.0	-
Telmessus cheiragonus	0.04	0	0
MOLLUSCA - GASTROPODA - no/m^2			
Acmaeidae, unid	-	4.0	-
Beringius kennicotti	0.04	0	0
Buccinum glaciale	0	0	0.02
Fusitriton oregonensis	0.2	1.0	1.0
Hermissenda crassicornis	0	0	0.02
Margarites pupillus	-	2.0	-
Neptunea lyrata	0.1	0	0.02
Trichotropis insignis	-	6.0	-
Trophonopsis lasius	-	1.0	-

TABLE 9
(continued)

SPECIES COMPOSITION OF KNOLL HEAD LAGOON STUDY AREA, AUGUST 1978

Dominant Taxa	Depth (m)		
	+0.3 to -0.6	-1.8	-3.6 to -4.8
MOLLUSCA - Pelecypoda - no/m^2			
Modiolus modiolus		261.0	
Musculus vernicosus		P	
Mya sp.		1.0	
Pododesmus macroschisma	0	1.0	0.2
MOLLUSCA - Polyplacophora - no/m^2			
Mopalia sp.		4.0	
Tonicella lineata		23.0	
ECTOPROCTA			
Costazia ?surcularia - % cover		0.3 ± 0.5	
ECHINODERMATA - no/m^2			
Crossaster papposus	0		0.02
Henricia sanguinolenta	0		0.05
Leptasterias ?hylodes	0	1.0	0.1
Ophiopholis aculeata	-	P	-
Strongylocentrotus drobachiensis	0.04	-	0.05

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Biomass estimates exceeded 1.5 kg/m^2 for each of these species. At -1.8 m, average densities decreased to a range of 0.8 to 1/m^2 for *Alaria* and 4.6 to 8/m^2 for *Laminaria*. *Agarum* became more common with greater depth but waS still relatively insignificant (Appendix F-2).

Directly below the algal belt, large species of the anemones *Tealia crassicornis* and *Cribrinopsis similis* were abundant.

With increasing depth below the algal belt, hard substrate supported an increasingly rich diversity of suspension feeders. *Modiolus* was patchy but extremely dense patches were observed. Estimated average density at 1.8 m was 261.0 individuals/m^2.

An additional 22 species of suspension feeders were recorded. Some of the major specieS were *Balanus rostratus alaskanus*, hydroids (*Abietinaria* spp.), the sponges *Halichondria panicea* and ?*Mycale lingua*, and, in deeper areas, the bryozoan *Costazia* ?*surcularis*.

Thirty-one species of predators and grazers were observed. At -1.8 m, the grazers, including the chitons *Tonicella lineata* and *Mopalia* sp., the gastropod *Trichotropis insignis*, and an unidentified limpet, were most abundant. Average densities were 23.0, 4.0, 8.0 and 4.0 individuals/m^2, respectively. Also abundant at this depth was the hermit crab *Pagurus hirsutiusculus*, with 5.0 indivuduals/m^2, and the small anemone *Anthopleura artemisia*, with 8.0/m^2.

At 3.6 to 4.8 m depths, the areas of cobble/gravel substrate areas were impoverished while bedrock and boulders had moderate epibenthic cover. Common species on the boulders included small *Agarum* and *Laminaria*, *Fusitriton oregonensis*, the bivalve *Pododesmus macroschisma*, the small asteroid *Leptasterias* ?*hylodes* and an occasional large *Strongylocentrotus drobachiensis*.

Fishes were uncommon throughout the area. Density of the whitespotted greenling *Hexagrammos stelleri*, most abundant fish, averaged 0.1/m (Table 10).

TABLE 10 FISH SPECIES COMPOSITION FOR KNOLL HEAD LAGOON SUBTIDAL AREA; 2 AND 5 AUGUST 1978

		Depth below MLLW (m)				
TAXA		+0.3-0.6	1.8	1.8	3.6-4.8	3.6-4.8
CHORDATA						
Hexagrammos decagrammus	($\bar{x} \pm s$)	0	-	0	0	0
	(no./m^2)	0	0.02	0	0	0
H. octogrammus	($\bar{x} \pm s$)	-	-	0.1 ± 0.3	0	0
	(no./m^2)	0.02	0.02	0.05	0	0
H. stelleri	($\bar{x} \pm s$)	-	0	0.3 ± 0.5	0	0.2 ± 0.5
	(no./m^2)	0.02	0	0.1	0	0.1
Hexagrammos sp, juvenile	($\bar{x} \pm s$)	0	-	0	0	0
	(no./m^2)	0	0.02	0	0	0
Transect Size (m^2):		2 x 30	1 x 50	0.5 x 5	2 x 30	0.5 x 5
No. of Quadrats:		1	1	16	1	25

3. The Biological Assemblage at White Gull Island

Reconnaissance dives were made on the west of lee side of White Gull Island in June, and along the exposed east side of the island in August (Figure 1). Intertidally, the lee side of the island comprised two substrates, i.e., a coarse gravel beach and sheer rock faces. These substrates extended subtidally and then graded through an area of low-relief cobble and small boulders to small gravel and shell debris, finally turning into silt and gravel flats in the southern entrance channel.

The only organism observed on the intertidal gravel beach was Littorina. Macrophytes were first encountered in the cobble and boulder field at 1.1 m below MLLW (Appendix C-1) but only extended to a depth of 3.6 m below MLLW. Important macrophyte species included Monostroma, Alaria taeniata, Desmarestia aculeata, and at deeper depth, Agarum cribrosum and Laminaria spp. Numerous hydroid and bryozoan species, an orange, encrusting sponge and the bivalves Astarte sp. and Macoma sp., formed the suspension-feeding component of the assemblage. Predator/scavenger species included the gastropods Boreotrophon spp., Buccinum glacialis, Natica clausa and Neptunea ?lyrata, three species of Leptasterias and whitespotted greenlings.

The intertidal sheer rock face extended subtidally to 2.3 m below MLLW. The assemblage was similar to that reported for the boulder field below.

The small gravel/shell debris flat appeared to be typical of deeper portions of Iliamna Bay. Observations out to the middle of the southern entrance channel at a depth of 4 m below MLLW revealed no visual change in substrate. Near slack tide, a fine layer of silt covered the bottom.

Below -2.8 m, the flat was completely devoid of macroalgae. The macrofauna comprised numerous deposit and suspension feeders, including a terebellid polychaete, the hydroids Abietinaria spp. and ?Obelia sp., the bryozoans Dendrobeania murrayana and Eucratea loricata, and the bivalve Clinocardium sp. Predators included the hermit crabs Elassochirus tenuimanus and

Pagurus ochotensis, the gastropods *Neptunea lyrata* and *Oenopota* spp., the large asteroid *Leptasterias polaris acervata*, whitespotted greenlings and rock soles. One of the more important epifaunal species was the sabellid polychaete *Schizobranchia ?insignis*. This tubicolous suspension feeder was observed in dense clusters up to 1.3 m in diameter and extending 0.3 m above the bottom. Hermit crabs and the snail *Neptunea* were occasionally observed in the midst of the clumps; both groups are reported to feed on *Schizobranchia* in this manner.

The exposed east side of White Gull Island comprises a broad intertidal bedrock shelf which abruptly breaks into a vertical face at approximately 1.6 m below MLLW. A steep talus slope commences at 4.4 to 5.4 m below MLLW and continued down to 11.1 m below MLLW, where a gravel/shell debris flat was encountered.

Although *Alaria* and *Laminaria* were abundant atop the bench, macrophytes were generally absent below its edge (Appendix G-2).

On the vertical rock face, suspension feeders dominated. Young specimens of the anemone *Metridium senile* (<10 cm high) were the most abundant form. Also common were the small sea cucumber *Eupentacta quinquesemita*, the anemones *Tealia crassicornis* and *Cribrinopsis* sp., several species of sponge, hydroids, bryozoans and tunicates and the predatory gastropods *Neptunea* and *Fusitriton*. Grazer species were of little importance.

The talus slope and boulder field were dominated by various suspension feeders. Important species included the orange, social tunicate *Dendrodoa pulchella*, the bryozoans *Costazia ?surcularis* and *C. nordenskjoldi*, the sponge *Mycale* and the barnacle *Balanus rostratus*. Coverage by these species was considerable; the epifaunal mat was complex.

The fine gravel/shell debris flat was not extensively surveyed, but had small rippled marks and a very thin deposit of silt. Numerous small pagurid crabs and *Leptasterias polaris* were observed occasionally.

4. The Biological Assemblage at Black Reef

Black Reef is a bedrock pinnacle surrounded by a talus slope. Subtidally, the reef has a vertical face with slight undercutting. The talus slope commences at a depth of about 4-6 m. With boulders up to 2 m in diameter and many crevices and small caves, surface relief is high. At about 9.3 m, rock gives way to a flat bottom of silty sand, gravel, and shell debris with small ripple marks. The reef is openly exposed to any wave action generated across lower Cook Inlet or from the intense "williwaw" winds jetting through the surrounding mountain passes (Figure 1).

The only significant macrophyte cover at the site occurred above 1.8 to 3.0 m. Algae included *Laminaria groenlandica*, *Alaria taeniata*, *Rhodymenia palmata*, and encrusting coralline algae. Macrophytes were totally lacking below 4.7 m (Appendix H).

Below the laminarian zone was located a zone of the anemone *Tealia crassicornis* and *Cribrinopsis*, and below that, a band of the small social tunicate *Dendrodoa pulchella*. The remainder of the rock face was dominated by various species of bryozoans sponges and *Balanus rostratus*. Beneath shallow overhangs the sea cucumbers *Psolus* sp. and *Eupentacta* and the gastropods *Callicstoma ligata* and *Margarites pupillus* were reported. The grazers *Tonicella* spp., *Mopalia* spp. and *Ischnochiton trifidus* were present but sparse. Finally at the base of the face, specimens of many *Boreotrophon clathrus* were feeding on in small patches of barnacles.

On the boulders at 4.7 m, a few of *Agarum* and *Rhodymenia* plants were the only macrophytes present. The area was occupied mostly by *Balanus rostratus*, the digitate bryozoan *Costazia* ?*surcularis*, the sponges *Mycale* ?*lingua* and *Halichondria panicea*, the tunicate *Dendrodoa pulchella*, and encrusting coralline algae. Also commonly observed was the clam *Mya truncata*, the small decorator crab *Oregonia gracilis*, and the brittlestar *Ophiopholis aculeata*. The latter was very abundant in crevices, among barnacles, in bryozoan colonies and crawling over rocks.

Away from the boulders at 9.3 m, the fine sand/gravel/shell debris substrate appeared impoverished. Several small hermit crabs and a single Fusitriton were the only epifauna recorded.

5. The Biological Assemblage at Turtle Reef

In August 1978, a brief reconnaissance dive was made among the eastern pinnacles at Turtle Reef, a broad intertidal shelf of fairly flat rock (Figure 1). The biota, typically intertidal, was dominated by the macrophytes Fucus, Alaria, Rhodymenia palmata, the barnacle Balanus, the grazers Acmaea and Tonicella lineata and the gastropod Littorina. Spongomorpha and associated diatoms were abundant on top of rocks. The anemones Anthopleura artemisia, Tealia crassicornis and Cribrinopsis were common in protected, low sites. The sponge Halichondria panicea formed well-developed mats in channels between the eastern and western rocks (Appendix I). In the lower intertidal zone, Laminaria and several rhodophytes were more abundant. Clusters of tunicates were evident and comprised the most obvious and abundant epifauna. Also common were the anemone Cribrinopsis , the tunicate Styela sp., and the brittle star Ophiopholis aculeata.

C. THE BIOLOGY OF MODIOLUS MODIOLUS

1. Habitat

The horse mussel, Modiolus modiolus, is typically found in aggregated patches or beds. Individuals are joined to rocks or each other by networks of byssal threads. Often the beds examined were so well stabilized by byssal attachments that it required 45 to 60 minutes for a diver to excavate a 1/4m area. They are usually buried in a silt, sand, cobble and shell debris substrate with just the tips of their shells exposed. These tips may be encrusted with epibiotic forms such as encrusting coralline algae, hydroids, bryozoans, sponges or have macrophytes attached. In some areas, e.g., in the entrance channel to Jakolof Bay, an overburden of Modiolus shell debris up to 15 cm thick is present; its function will be discussed below.

Mature beds of Modiolus form well-stabilized matrices attractive to numerous infaunal and epifaunal forms. Infaunal animals frequently encountered include sea cucumbers, brittle stars, sabellid and nereid polychaetes, nemerteans, echiurid worms, and the clams Saxidomus, Hiatella and Macoma.

Some of the more prevalent epifaunal forms included sea urchins, the large snails Fusitriton and Neptunea, various hermit crabs and other crustaceans, and the starfish Evasterias, Pycnopodia, Orthasterias, and Leptasterias polaris var. acervata.

2. Distribution

The horse mussel was the dominant suspension feeder at several locations in Kachemak Bay, Kamishak Bay, and lower Cook Inlet generally (Table 11). It was generally observed at sites characterized by light to moderate turbidity, at least moderate tidal currents, and a gravel/cobble or bedrock substrate. It is therefore likely that it is common along the entire northern shelf of the Kachemak Bay and has, in fact, been observed in nearly every area examined there. In contrast, the only location in which it has been found on the south side of the bay was in the entrance to Jakolof Bay, a site exposed to strong tidal flow of moderately turbid water out of Jakolof Bay. However, Modiolus was not observed at any of the "clean" water sites in Kachemak Bay, i.e., areas exposed directly to oceanic water flowing into Kachemak Bay out of Kennedy Entrance.

Contrary to expections, Modiolus was not abundant at most sites examined along the west side of lower Cook Inlet. Although the species was reported in silty cobble substrates near Iniskin Bay, and two sites in Chinitna Bay, it was common only at one site (Lees and Houghton 1977). In northern Kamishak Bay, Modiolus was noted subtidally at only one location (Knoll Head Lagoon site), where densities were moderate although distribution was quite patchy. Clumps tended to be associated with pockets in the bedrock. However, one large clump formed a dense pillow like mass on a large flat boulder; the shells were heavily encrusted with coralline algae. This mass, appearing to consist mainly of large adult mussels, strongly resembled the dense beds of Mytilus observed in the intertidal zone on the east side of the inlet.

Modiolus was also observed in the low intertidal zone at Scott and Vert Island in pockets in the bedrock. Most of the remaining areas surveyed were vertical rock faces, boulder slopes, or sand or mud bottoms, i.e., apparently unsuitable for colonization by Modiolus. Thus, availability of suitable substrate impose a severe limitation on the distribution of Modiolus in the shallow inner portions of Kamishak Bay.

3. Size Structure

Specimens were collected at various sites to enable examination of distributions and biomass patterns. Strong geographic differences were apparent.

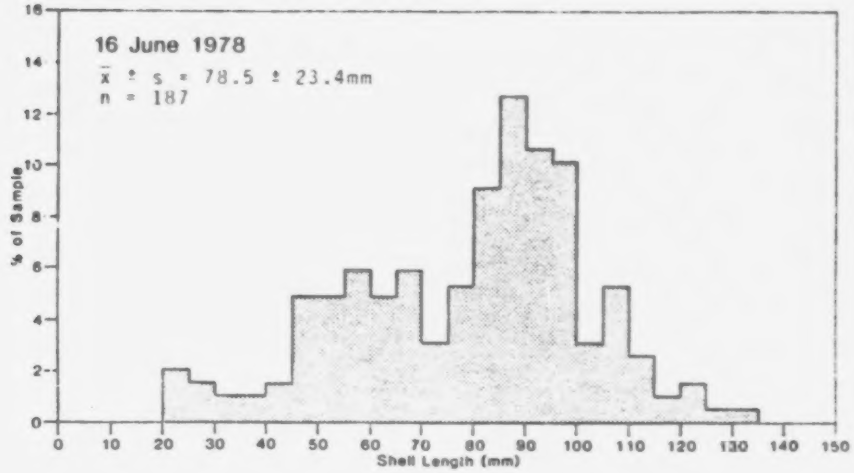
In the entrance channel of Jakolof Bay, collections were made on the shallow reef protruding into the channel (3 m deep) and along the base of that reef, on the floor of the channel (11 to 12 m deep). Both populations were dense and had high standing stocks (Table 11). The size frequency curve was bimodal and dominated by large individuals, but the populations contained a large proportion of younger animals, suggesting that recruitment, although not massive, was common and fairly reliable (Figures 2 and 3). Mean shell length was generally slightly larger in channel populations than in populations atop the shallow reef. This, coupled with generally higher densities, acted to produce higher standing stocks in the channel (Table 11). The populations in the channel had, in fact, the highest densities and biomass observed in lower Cook Inlet, i.e., 672 individuals/m^2 and 14,569.4 g wet tissue/m^2 .

On Archimandritof Shoals, the population trends were more variable. At a depth of 15.5 m, the population size structure was similar to that described for Jakolof Bay, i.e., although it was dominated by large adults, younger animals were common (Figure 4). Density and biomass were lower than at Jakolof Bay but average shell length was larger (Table 11). At shallower depths, average size, density and biomass were all substantially lower. In

TABLE 11

SUMMARY OF POPULATION DATA FOR MODIOLUS MODIOLUS FROM SUBTIDAL SITES IN KACHEMAK AND KAMISHAK BAY

Site	Collection Date	Approximate Depth (m)	n	Number per m	Mean Length (cm)	Population Type	Wet Tissue Weight (g/m)
Jakolof Bay							
Channel	6/16/78	11	187	374	78.4 23.4	1	6,766.2
	9/14/79	12	168	672	83.3 27.4	1	14,569.4
Reef							
	3/12/77	3	45	180	77.3 20.8	1	2,164.2
	3/29/79	3	300	600	82.4 20.9	1	11,587.9
	9/14/79	3	84	336	66.8 19.7	1	3,983.6
Archimandritof Shoals	8/03/76	4	-	∿ 2	-	-	-
	8/03/76	11	43	∿30	72.1 25.3	1	845
	6/28/78	5	-	18	-		-
	6/28/78	7	44	63	81.4 20.5	1	607.2
	7/10/78	15	169	134	90.3 25.5	1	3,238.0
Bishop's Beach	8/03/76	15	30	∿15	102.2 16.3	2	710
Bluff Point	10/25/75	12	45	57	124.3 11.8	2	4,347.5
	7/31/75	13	24	8	121.8 10.5	2	562.7
Anchor Point	7/22/76	15	15	10	97.0 12.9	2	430
Knoll Head Lagoon	8/02/78	2	37	148	51.9 24.0	1	870.8
	8/02/78	2	111	444	81.3 35.4	1	7,352.4
	8/05/78	2	141	564	77.3 13.6	1	6,646.0
	8/05/78	2	95	380	78.6 13.1	1	4,625.6



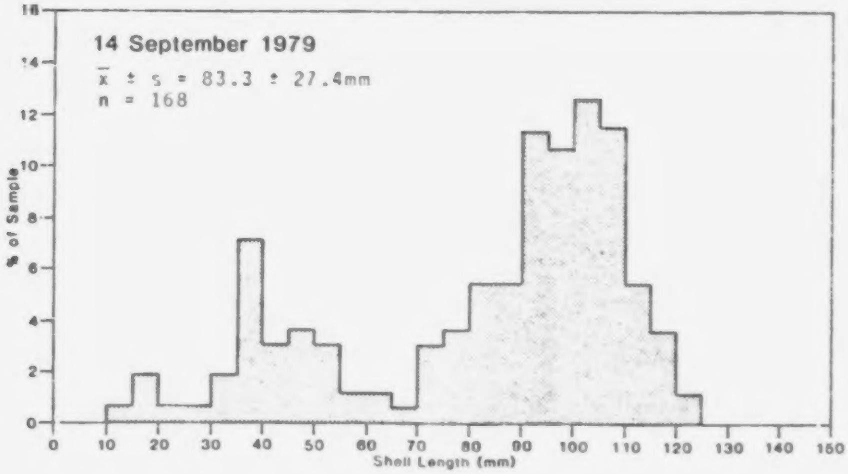


FIGURE 2

SIZE STRUCTURE OF *Modiolus modiolus* POPULATIONS
IN ENTRANCE CHANNEL TO JAKOLOF BAY; DEPTH ABOUT 10 m

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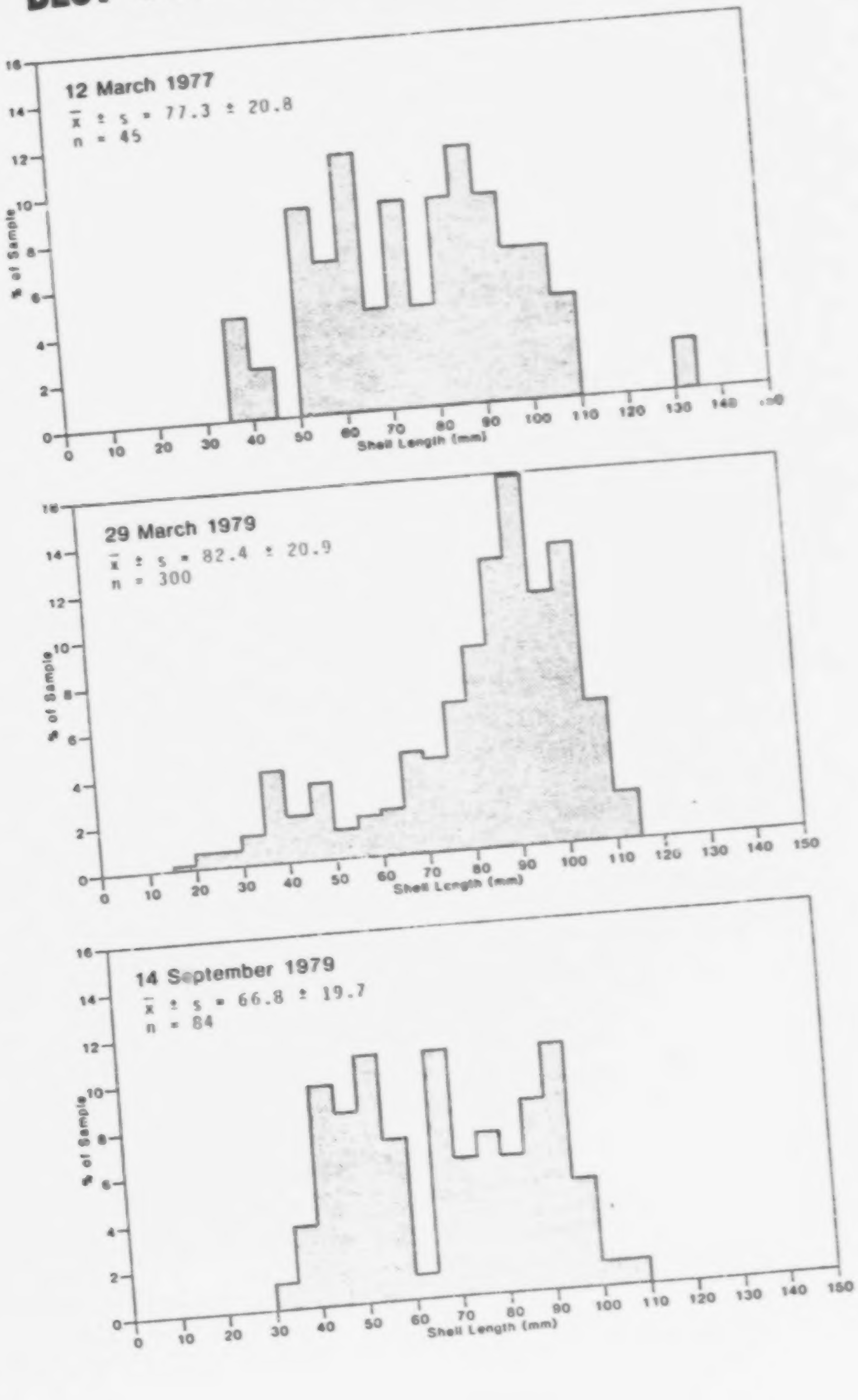

12 March 1977
$\bar{x} \pm s = 77.3 \pm 20.8$
n = 45

29 March 1979
$\bar{x} \pm s = 82.4 \pm 20.9$
n = 300

14 September 1979
$\bar{x} \pm s = 66.8 \pm 19.7$
n = 84

FIGURE 3

SIZE STRUCTURE OF Modiolus modiolus POPULATIONS ON REEF IN ENTRANCE TO JAKOLOF BAY; DEPTH ABOUT 2 m

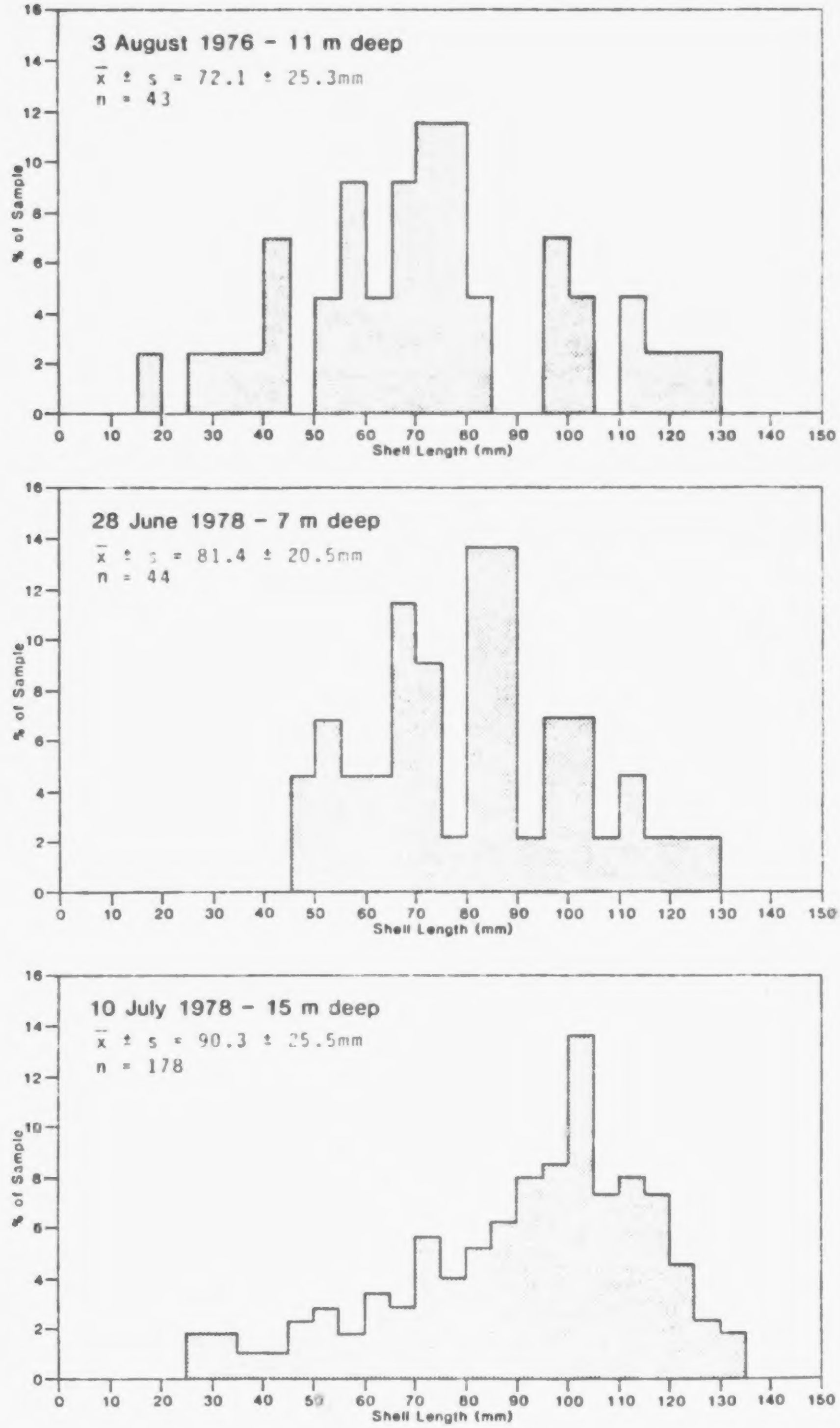

FIGURE 4

SIZE STRUCTURE OF Modiolus modiolus POPULATIONS ON ARCHIMANDRITOF SHOALS addition, loose shell debris became less abundant. Population size structures indicated that recruitment to the populations was commonplace but not massive. Density became greatly reduced at a depth of about 5 m, near the interface of the cobble and sand substrates. These trends probably are related to the patterns of physical rigors occurring on the shoals during fall and winter storms. Every year, waves generated by southwesterly storms sweep across the shoals during this period, bringing ashore large quantitites of coal from offshore coal seams. The migration of these blocks of coal undoubtedly becomes progressively more violent and damaging in shallow water, thus increasing mortality rates. Furthermore, with increasing proximity to the sandy substrate of the beaches on Homer Spit, the amount of large-grain suspended sediment increases, thereby increasing the probability of abrasion damage, temporary burial and suffocation. The consequences of these effects would be a progressive decrease in average age (and thus size), density and biomass in shallow water.

Off nearby Bishop's (Seafair) Beach, at a depth of 14.6 m, estimates of density and biomass based on visual counts and a removal were about 15 individuals/m^2 and 710 g tissue/m^2 (Table 11). The size frequency of this small sample was strongly unimodal; the population comprised mainly very large individuals. The virtual absence of small individuals implies that recruitment has occurred only infrequently in the recent past (Figure 5). Biomass and density were also low (Table 11).

Populations at Bluff Point were sampled only twice and the sampling times and locations differed considerably. However, the data indicate that these populations were composed of very large individuals (Figure 6). Densities were low and biomass was variable (Table 11). These patterns were observed in several other areas examined off Bluff Point where samples were not removed (Lees and Houghton 1977). Often, the areas were also inhabited by fairly dense populations of very large Evasterias troschelii, which were feeding on Modiolus. Also, the areas were littered with Modiolus shell debris. The implication is that these areas once supported thriving populations of Modiolus but that they are now overexploited by predators such as Evasterias, and that recruitment success is sporadic.

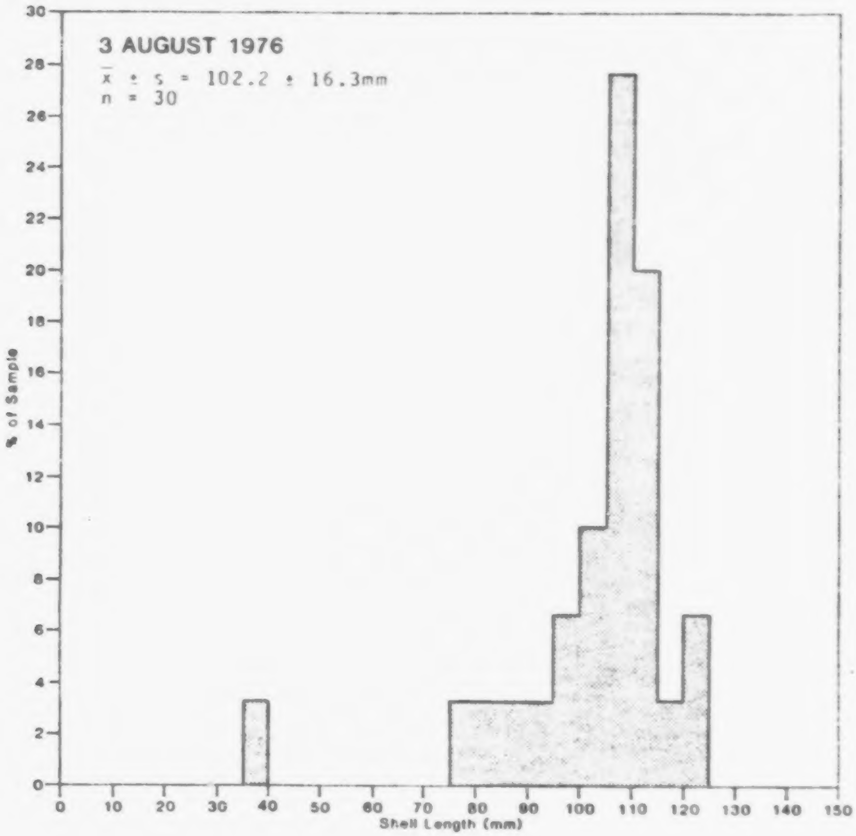

FIGURE 5

SIZE STRUCTURE OF A Modiolus modiolus POPULATION FROM OFF BISHOP'S BEACH; DEPTH ABOUT 14.6 m

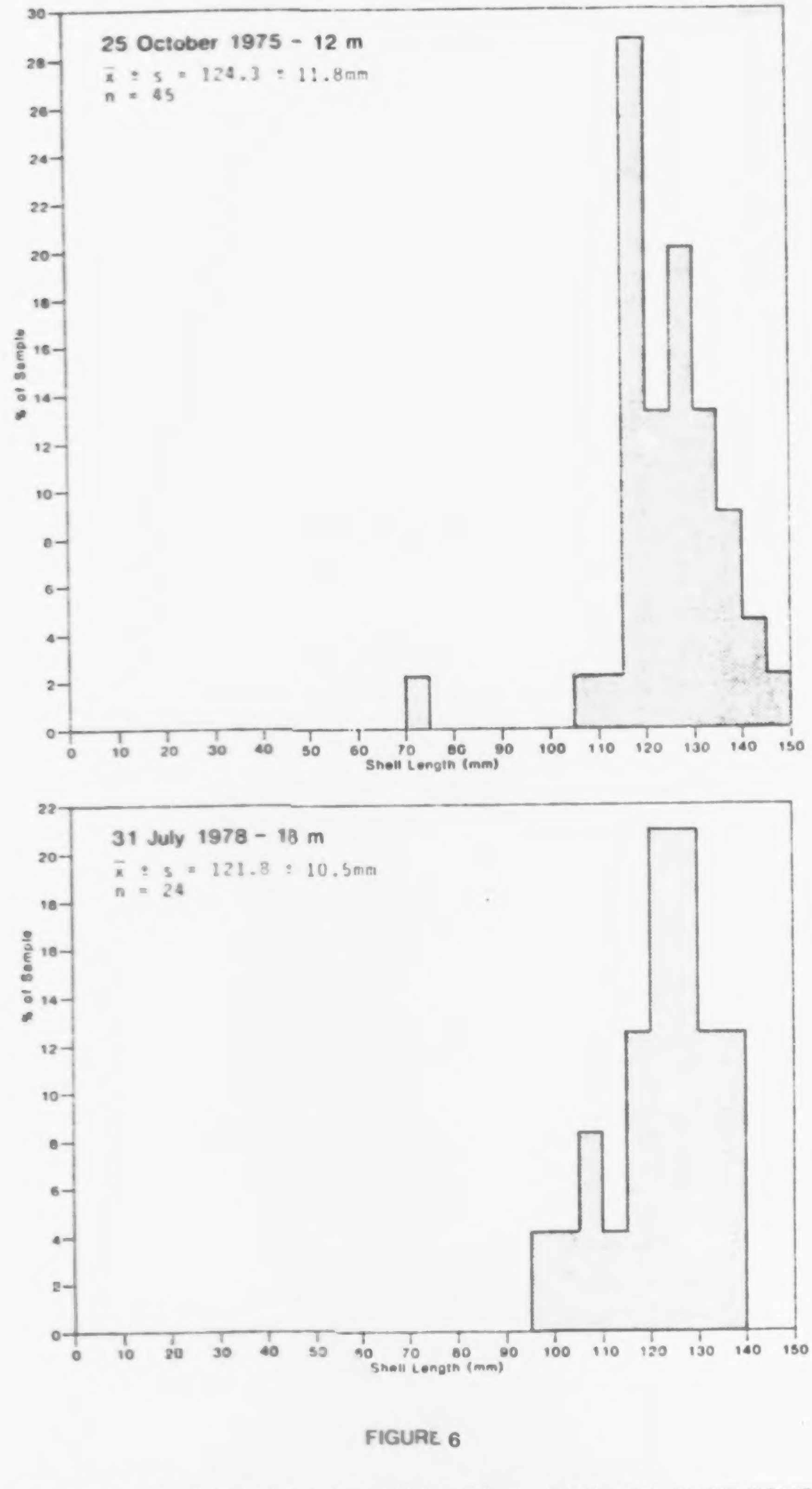

FIGURE 6

SIZE STRUCTURE OF Modiolus modiolus POPULATIONS OFF BLUFF POINT

Patterns observed off Troublesome Creek and Anchor Point were similar to those described for Bluff Point but recruitment may be successful occasionally (Figure 7). Average size was somewhat smaller (Table 11), and biomass was the lowest recorded.

On the west side of the inlet, the only well-developed subtidal beds of Modiolus were encountered at the Knoll Head Lagoon site, along the rocky shore between Iniskin and Iliamna Bays. However, sparse beds were encountered in the low intertidal zone at Scott and Vert Islands, in front of Iniskin Bay. Most of the beds observed at Knoll Head Lagoon were at a depth of about 2 to 3 m, just below the intertidal zone. All the populations sampled in this area gave evidence of successful recruitment (Figures 8 and 9), and some of the populations showed the strongest recruitment observed in any of the populations sampled, e.g., Figure 9. The populations were distributed patchily in small groups nestled in depressions in the bedrock. This may account for the strong difference in size structure between the groups sampled and represented in Figures 8 and 9. The effects of either ice scour or predation would be more discrete in such a habitat, leading to greater heterogeneity in size structure. Density and biomass were moderate, despite the patchiness (Table 11).

4. Predation and Secondary Production

We attempted to determine growth rates for Modiolus in a plot in the entrance channel of Jakolof Bay by notching shells a predetermined distance from the shell margin at the exposed (posterior) end of the shell. The reason for notching the shell away from the margin was to preclude damaging the mantle or destroying the integrity of the mantle cavity and thus exposing the marked animals to increased predation rates. In order to obtain access to the animals for this operation, it was necessary to remove the epifauna (hydroids and bryozoans), small red algae and shell debris. The latter was in a loose layer nearly 10 cm thick. When we returned about a year later to recover the notched animals, all animals in the plot had been removed and

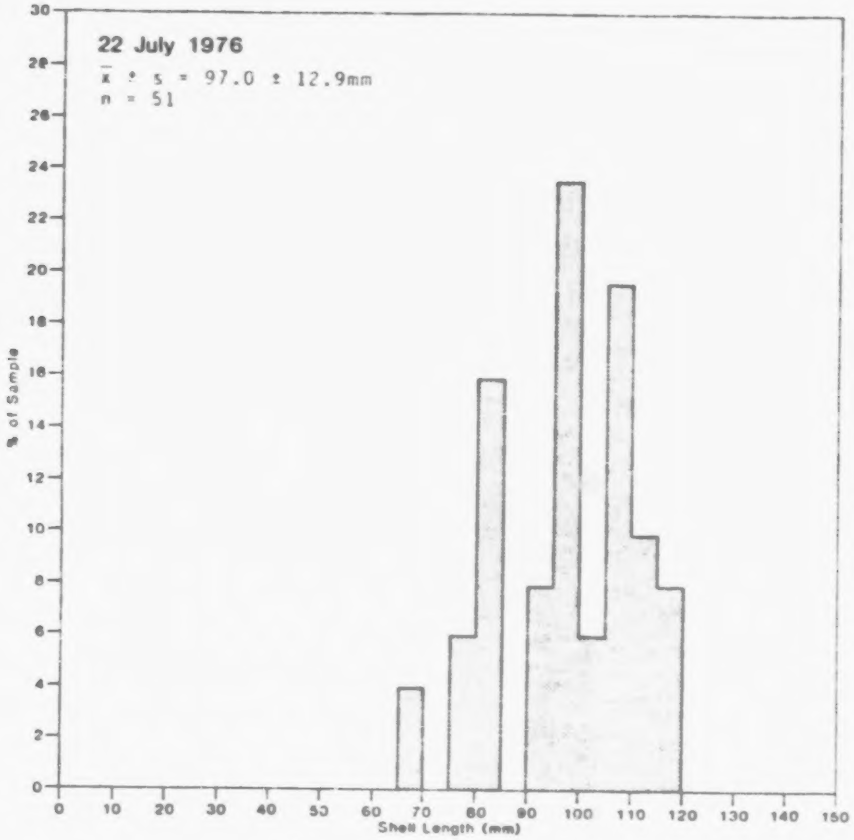

FIGURE 7

SIZE STRUCTURE OF A Modiolus modiolus POPULATION OFF ANCHOR POINT; DEPTH ABOUT 15 m

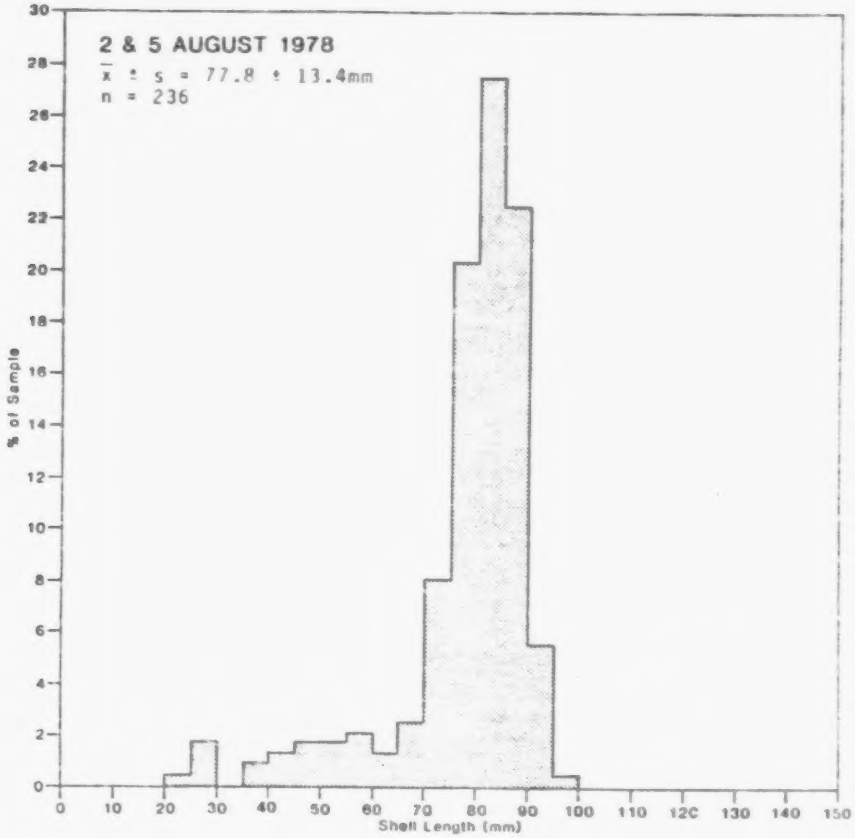

FIGURE 8

SIZE STRUCTURE OF SOME *Modiolus modiolus* POPULATIONS AT THE INNER LEVEL AT THE KNOLL HEAD LAGOON SITE; DEPTH ABOUT 1.8 m

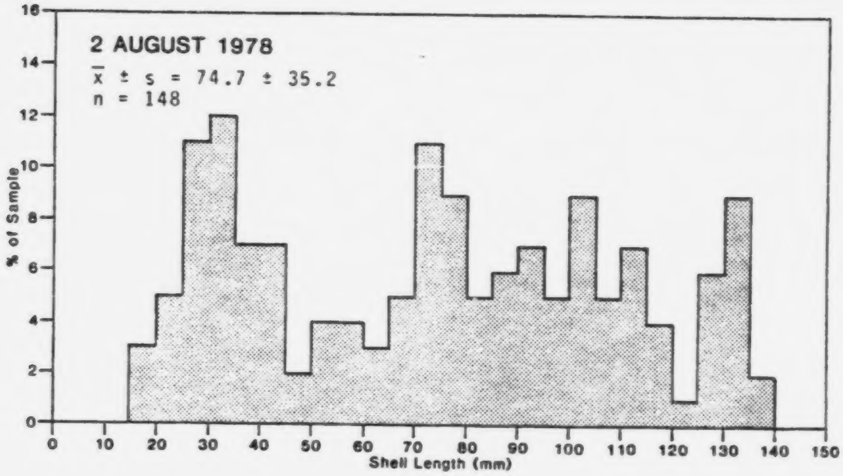

FIGURE 9

SIZE STRUCTURE OF Modiolus modiolus POPULATIONS
AT THE INNER LEVEL AT THE KNOLL HEAD LAGOON SITE; DEPTH ABOUT 1.8 m

consumed by starfish, leaving a conspicuous depression in the surrounding mussel bed, and exposing the cobble matrix. Thus, it appears that the epibiota and shell debris provide important protection against predation to Modiolus, at least in certain circumstances. However, in areas such as Archimandritof Shoals where surge action is a significant factor, shell material is frequently sparse or lacking as it is resuspended and swept out of the area by storms.

Although numerous actual or potential predators have been observed or recognized, the observed effect of predators on Modiolus varied from apparently low at Knoll Head to very intense at Jakolof Bay. At the latter, its major predators were the starfish Pycnopodia helianthoides, Evasterias troschelii and Orthasterias koehleri. The density relationships for these starfish were 1.25:6.125:1.0, respectively, and their actual densities in the channel approximated 0.20, 0.98, and 0.16 individuals/m^2 (Table 5). Pycnopodia had the most varied diet, feeding on 13 different species; of the 157 individuals examined, about 12.7 percent were consuming Modiolus and 56.7 percent were not feeding (Figure 10). Evasterias fed on only 3 species; of the 292 individuals examined, 20.9 percent were feeding on Modiolus and 75.7 percent were not feeding. Orthasterias fed on only 2 species; of the 42 individuals examined, 28.6 percent were feeding on Modiolus and 66.7 percent were not feeding. Thus, of the 491 starfish examined, 19.0 percent were feeding on Modiolus and 66.8 percent were not feeding at all (Figure 10).

Assuming a constant annual rate of consumption by all species, these consumption ratios in the channel extrapolate to 0.025 mussels consumed/m^2/-day by Pycnopodia, 0.205 mussels consumed/m^2/day by Evasterias, and 0.046 mussels consumed/ m^2/day by Orthasterias, or 9.3, 74.8, and 16.8 mussels/m^2/ year, respectively. This totals about 100 mussels consumed/m^2/year, or about 19 percent of the population per year. From these data, it appears that Evasterias was the more important predator of the three from the viewpoint of Modiolus.

We examined size data collected during this study for relationships beween the size of a predator and its prey, and found that size is important.

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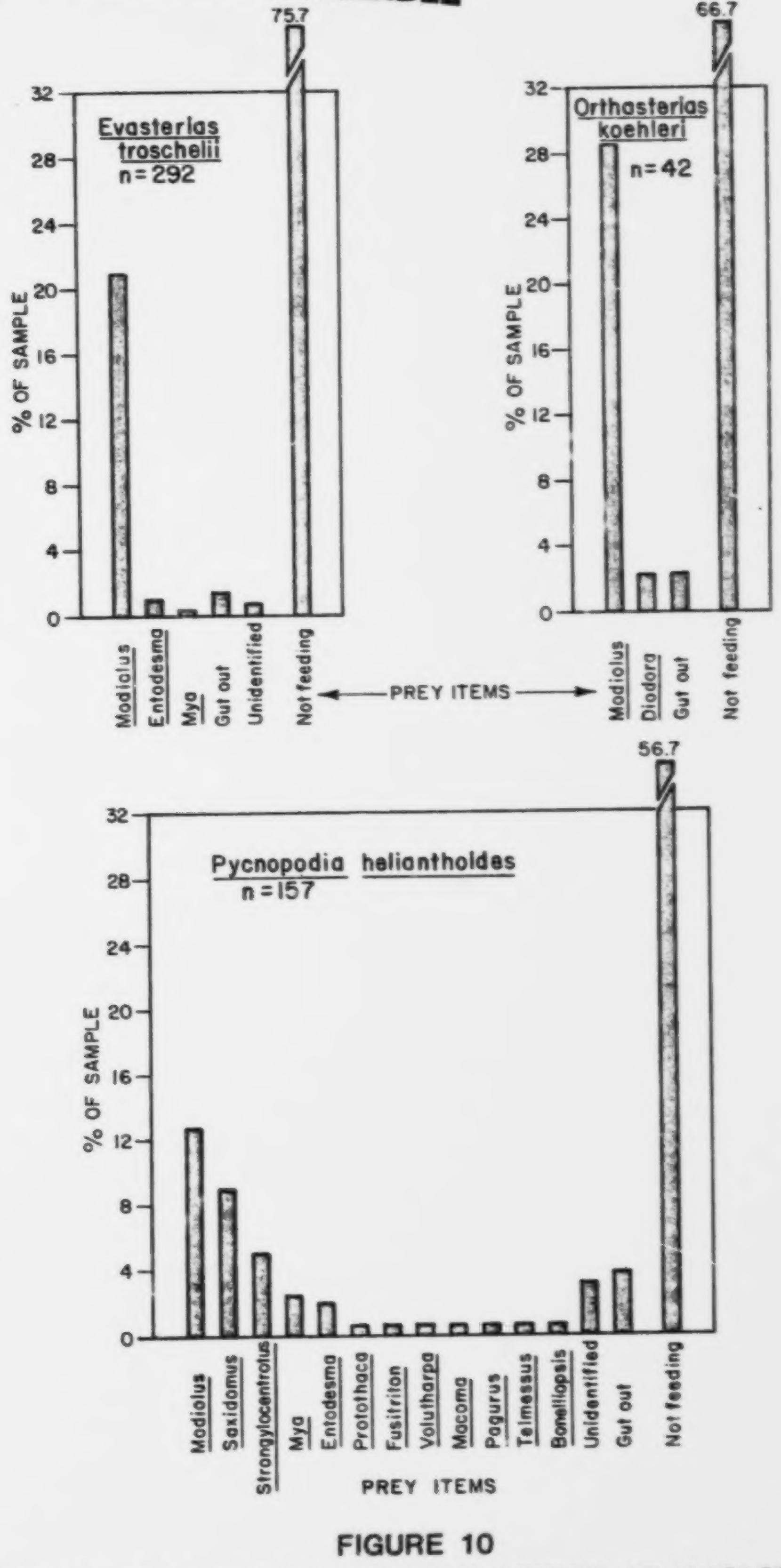
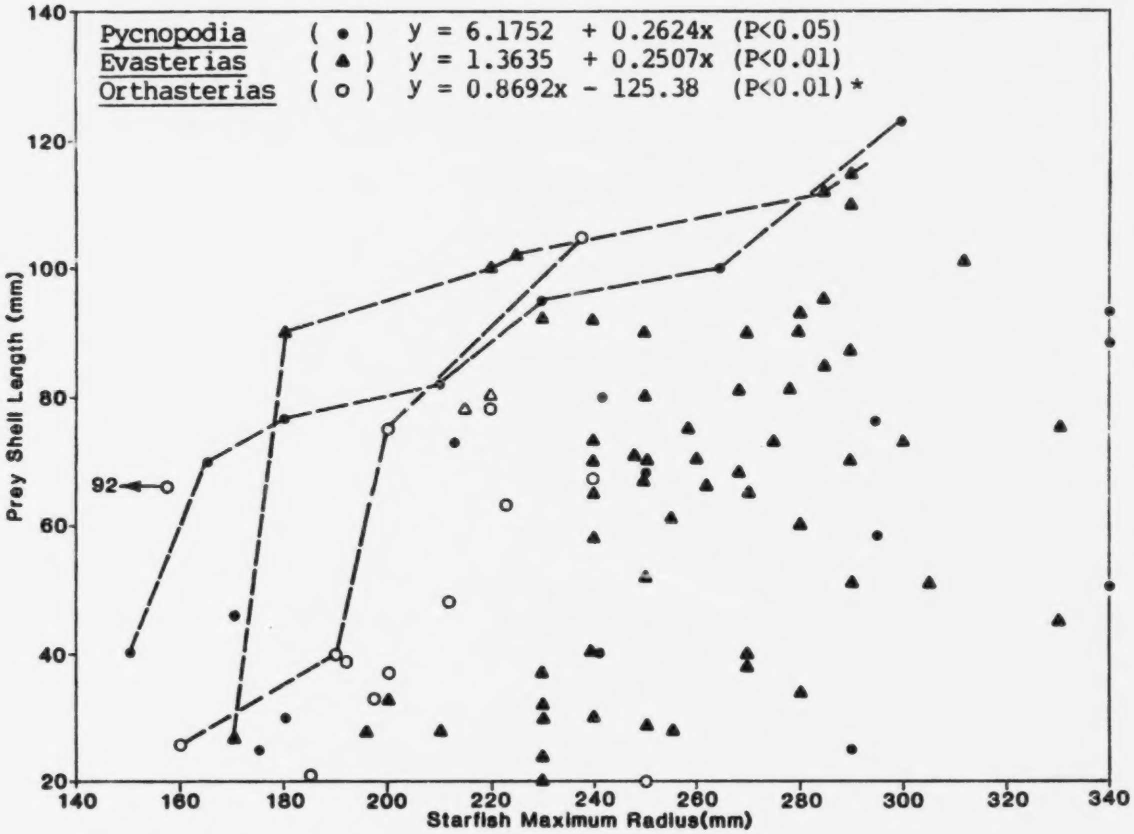


FIGURE 10
PREY ITEMS OF MAJOR STARFISH SPECIES AT JAKOLOF BAY
SEPTEMBER-NOVEMBER 1978

In all three species, the correlation was positive and significant (Figure 11). As individuals of the predatory species become larger, they select for larger prey. However, these relationships do not appear to differ a great deal among the species. In fact, the agreement among the dashed lines describing the size-specific prey-size limitations for each predator is remarkable (Figure 11).

Size distributions of the prey populations were compared with that of the "source" population to examine prey selection strategies more closely. Analysis with the Kolmogorov-Smirnov two-sample test indicated that the size structures of all prey populations were significantly smaller than that of the source population (Figure 12). The probability that the prey selected by Pycnopodia and Evasterias represented a random selection from the source population was low ($P<0.01$), and by Orthasterias, quite low ($P<<0.001$). Nearly 50 percent of the mussels taken by Pycnopodia and Evasterias were below 65 mm shell length, in contrast to over 78 percent by Orthasterias. Over 70 percent of the prey were smaller than the average size for the source population. The size distributions of prey captured by Pycnopodia and Evasterias were not statistically distinct from each other ($P>0.3$), but Orthasterias differed from both of them strongly ($P<<0.001$). These patterns suggest that once Modiolus attains a certain size, it acquires a degree of protection from predation, i.e., it has a refuge in size. However, this "refuge" may be as much a result of probabilities as a matter of physical limitations for the predator. The density of large predators and prey is low and the probability encounter is thus low. Furthermore, it is obvious from the data points in Figure 11 that large starfish do not restrict prey capture to large prey.

This aspect of predation strategy has bearing on estimation of secondary production for Modiolus. Specifically, these starfish crop about 20 percent of the individuals in the prey populatations annually. However, because selection is biased toward smaller prey, it is probable that somewhat less than 20 percent of the biomass is removed. These estimates suggest a turnover time in excess of five years and secondary production of somewhat less



Notes:

Dashed lines connect the data points describing the size-specific prey size limitations for each predator

* Data for the largest and smallest starfish omitted

FIGURE 11

RELATIONSHIPS BETWEEN SIZES OF STARFISH PREDATORS AND THEIR PREY, Modiolus FROM JAKOLOF BAY

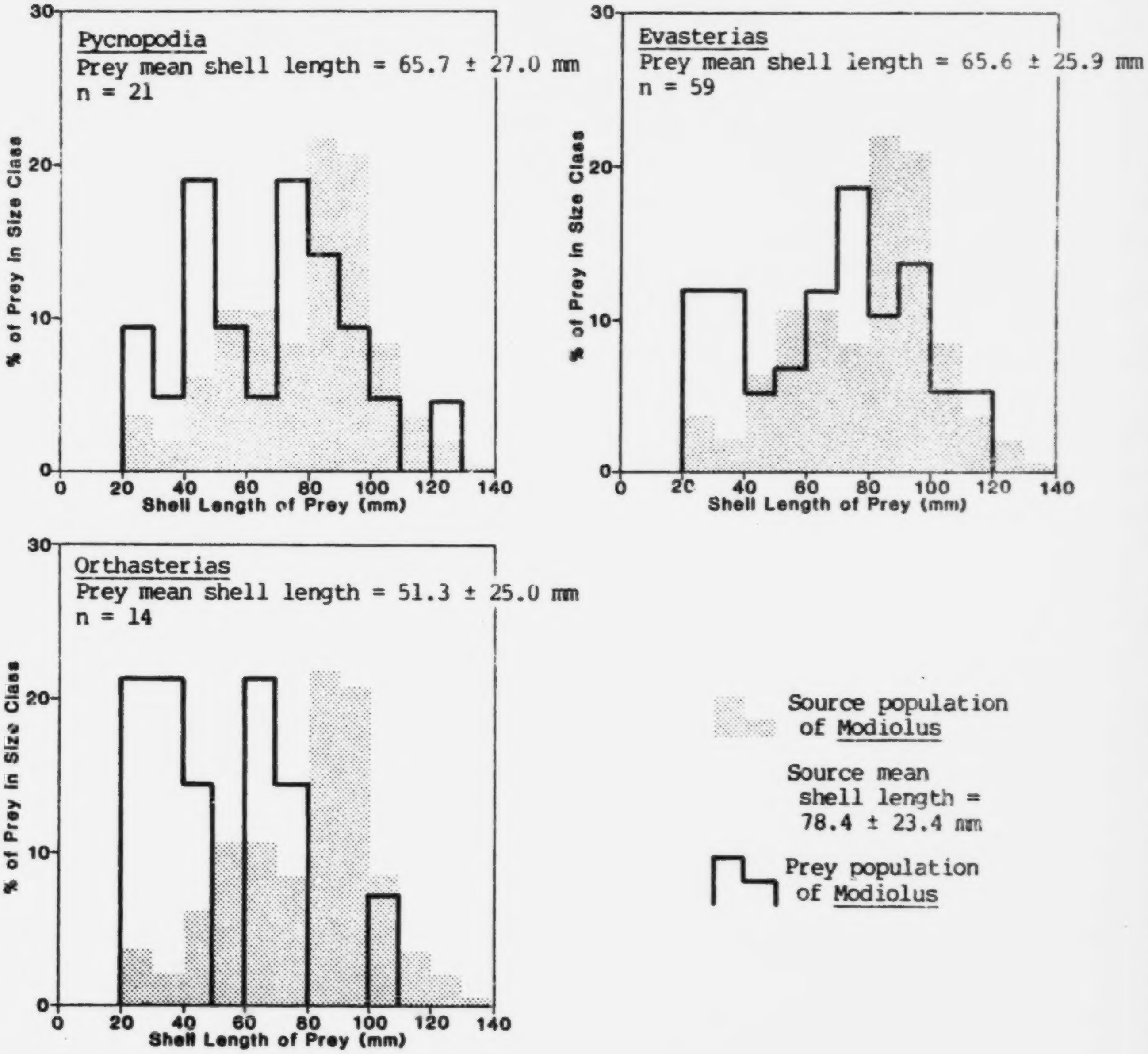


FIGURE 12

COMPARISONS OF SIZE DISTRIBUTIONS OF MODIOLUS
SELECTED AS PREY BY STARFISH
TO THAT OF THE NATURAL SOURCE POPULATION AT JAKOLOF BAY

2.0 kg wet tissue/m/year. In addition, the population produces a substantial quantity of gametes each year. In any event, however, the productivity: biomass ratio is probably considerably less than 0.5, despite the high level of tissue productivity.

Other predators are known or suspected to exert significant pressure on *Modiolus* populations in lower Cook Inlet. The starfish *Leptasterias polaris* var. *acervata* is important on Archimandritof Shoals, at Bluff Point, and on the west side of lower Cook Inlet. In some of these locations, it replaces *Evasterias*. Common eiders, the largest of the sea ducks, feed heavily on *Mytilus*, and flocks are commonly observed feeding in areas with *Modiolus* beds. This includes Archimandritof Shoals in winter and spring, and areas in Kamishak Bay during the winter, spring, and summer. Although consumption has not been observed directly, eiders have been observed feeding at the surface on mussels under conditions that would preclude taking *Mytilus*; however, removal of adult *Modiolus* from a bed might be quite difficult. Potentially important predators include sea otters, dungeness and king crabs, especially on the northern shelf of Kachemak Bay in late summer and fall.

D. Feeding Observations on Benthic Invertebrates

During this study, we collected numerous feeding data. In addition, we have summarized previously collected data as it pertains to the biotic assemblages above. Computer printouts of this summary are presented as appendices (Appendices J to M). Moreover, these data have been used to construct a summary of the trophic structure for each of the major assemblages described bove (See Discussion).

A considerable amount of feeding data was collected for sea stars because they are an abundant, important, conveniently observable predator. Diets of eleven abundant starfish are compared in Table 12. Basically four types of diets could be distinguished, namely, 1) sponge specialists, 2) specialists on soft-bodied animals, 3) specialists on echinoderms, and 4) generalists. Group 1, comprising only *Henricia* spp, is controversial

TABLE 12

Comparison of Prey Species used by Predatory Starfish
Numbers are the Relative Frequency (%) at Which Each Prey Item
Was Found in Feeding Observations; "x" Indicates Occurrence

PREDATOR

	Henricia leviuscula	Henricia sanguinolenta	Pteraster tesselatus	Dermasterias imbricata	Solaster stimpsoni	Solaster dawsoni	Evasterias troschelii	Pycnopodia helianthoides	Orthasterias koehleri	Leptasterias polaris var. acervata	Crossaster papposus
Porifera, unid	50	78	21	10							
Cliona celata	50										
Esperiopsis spp.			32								
Mycale spp.		22		x							
Hydroida, unid				4							7
Abietinaria spp.			11	x							7
Actiniaria, unid			x		13						
Anthopleura artemisia				x							
Metridium senile				69							
Tealia crassicornis				10							
Ectoprocta, unid											14
Alcyonidium spp.											x
Flustrella gigantea			x								x
Microporina borealis			x								x
Polychaeta											
Cistenides granulata								c*		4	
Gastropoda											
Acmaeidae, unid							x		x		
Diodora aspera									x		
Fusitriton oregonensis								x			
Natica clausa							x	x			
Neptunea spp.											x
Rostanga pulchra											7
Volutharpa ampullacea								x			
Polyplacophora, unid											14
Katharina tunicata							x				
Mopalia spp.										x	

TABLE 12
(Continued)

PREDATOR

	Henricia leviuscula	Henricia sanguinolenta	Pteraster tesselatus	Dermasterias imbricata	Solaster stimpsoni	Solaster dawsoni	Evasterias troschelii	Pycnopodia helianthoides	Orthasterias koehleri	Leptasterias polaris var. acervata	Crossaster papposus
Pelecypoda											
Clinocardium spp.							x			x	
Entodesma saxicola							x	x	x		
Humilaria kennerlyi									12		
Macoma spp.							x	x		x	
Modiolus modiolus							43	23	53	12	
Musculus discors							x		6	x	x
Mya spp.							x	3		12	
Mytilus edulis							10				
Panomya ampla								x			
Pododesmus macroschisma									x		
Protothaca staminea							x	x		x	
Saxidomus giganteus							x	25			
Serripes spp.							x				
Tresus capax							x				
Crustacea											
Balanus sp., unid							x		4	28	
B. cariosus							6				
B. crenatus							14		x		
B. glandula										4	
B. nubilus									x		
B. rostratus										x	
Paguridae, unid								x			
Pandalus spp.							x				
Telmessus cheiragonus								x			
Echiura											
Bonelliopsis alaskanus					38			x			
Tunicata, unid					x				x		
Colonide tunicate			x								
Halocynthia aurantium									x		

TABLE 12
(continued)

PREDATOR

	Henricia leviuscula	Henricia sanguinolenta	Pteraster tesselatus	Dermasterias imbricata	Solaster stimpsoni	Solaster dawsoni	Evasterias troschelii	Pycnopodia helianthoides	Orthasterias koehleri	Leptasterias polaris var. acervata	Crossaster papposus
Echinodermata											
Cucumaria spp.				3	38	67		x			
Dermasterias imbricata								x			
Evasterias troschelii					6	33					
Strongylocentrotus drobachiensis				x				25			x
Number of observed feedings	-	9	19	73	23	-	809	167	83	25	14
Number of prey species	2	2	7	8	5	2	18	17	12	11	11

* Common in other locations

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because of its mode of feeding (Mauzey et al. 1968). Feeding observations are based on visual assessment of damage to the sponge under a specimen of Henricia; the surface of the sponges appeared bleached and damaged. In some cases, the stomach of H. sanguinolenta was partially extruded. Attempts to find spicules in the stomach were not successful, but it is possible that spicules are not "ingested". Group 2, a loose collection, comprises Pteraster and Dermasterias. The former appears to limit its prey to sponges, cnidarians and bryozoans, whereas the latter feed on a broader variety of taxa (Table 12; Rosenthal and Chess 1972). Group 3 was restricted to starfish of the genus Solaster; predation of this group on other echinoderms, especially starfish and sea cucumbers, has been well documented (Mauzey et al. 1968). Group 4 comprises Evasterias, Pycnopodia, Orthasterias, Leptasterias polaris var. acervata, and Crossaster. All but the latter fed on a broad variety of clams, snails and barnacles; only two fed on other echinoderms or on tunicates, and only Crossaster fed on cnidarians or bryozoans. Although the latter fed on a broad range of prey species, it exhibited no strong preferences in choice. Most of its prey were not selected by any other sea star. Therefore, although a generalist, it showed little relationship to the other generalists.

An interesting trend in these groups is that Groups 1, 2, and 3 included only members of the order Spinulosa whereas Group 4 included mainly members of the order Forcipulata. Group 4 alone fed on clams and snails, both of which include many community dominants and contribute substantially to biomass.

The remaining data are considered most useful for indicating some of the predator-prey interactions but should not be considered complete or repre- observations and collections have been too biased.

E. SOFT SUBSTRATES

1. The Biological Assemblage at Mud Bay

Mud Bay in upper Kachemak Bay has a flat mud bottom lacking in any surface relief except for sparsely scattered shell debris and small boulders.

These boulders were probably transported to the sea by ice rafting from local drainages.

Reconnaissance dives were made at sites 1.5, 4.6, 6.1, and 10.7 m below MLLW. Species composition of the assemblages observed in the three deeper dives was generally similar (Table 13). Common epifaunal forms included small specimens of the hermit crabs *Labidochirus splendescens* and *Pagurus capillatus*, and larger crabs such as *Telmessus cheiragonus* and *Chionoecetes bairdi* (young); juveniles of the sea pen *Ptilosarcus gurneyi* were sparse. Common infaunal forms included suspension-feeding brittle stars (?*Amphiodia* sp.), deeply buried but with erect, exposed arms, and small tubicolus spionid and maldanid polychaetes. At 6.1 and 10.7 m, a large assortment of the predatory snails (*Oenopota* spp.) was observed. Densities of 2.5 and 9.0 individuals/m^2, respectively, were estimated for the two sites. Small cottids and flatfish were present at densities of 0.1 and 0.2/m^2 (Table 13); Appendix N).

The available hard substrate at three deeper stations was fairly well covered by the barnacle *Balanus rostratus alaskanus*, the anemone *Metridium senile*, and the serpulid polychaete *Crucigera zygophora*. *Strongylocentrotus drobachiensis* was also common on these rocks. Plants were rare.

At a depth of about 1.5 m, large patches of *Mytilus edulis* were observed Growing attached to the mussels were the algae *Monostroma fuscum*, *Porphyra* sp., *Spongomorpha*, *Desmarestia aculeata* and *Alaria taeniata*. The sea stars *Evasterias troschelii*, *Leptasterias hexactis*, and *L. ?hylodes* were also present. This site was typical of the low intertidal zone in Mud Bay (Table 14).

2. The Biological Assemblage at Cottonwood Bay

At Cottonwood Bay, we examined a 1.2 km long transect through the low intertidal and shallow subtidal zones to (0.6 to 2.5 m below MLLW) during a high tide. The transect was divided into three sections, i.e., east of the base camp, in front of the base camp and west of the base camp.

TABLE 13 SPECIES COMPOSITION FOR MUD BAY SUBTIDAL AREA; 10 JULY 1978

TAXA		Depth below MLLW (m)			
		10.7	10.7	10.7	11.3
CNIDARIA - Hydrozoa					
Abietinaria spp	($\bar{x}$ ± s)	0	1.8 ± 1.3	-	-
	(no./m^2)	0	0.4	-	-
Tubularia sp	($\bar{x}$ ± s)	0	0.2 ± 0.4	-	-
	(no./m^2)	0	0.04	-	-
CNIDARIA - Anthozoa					
Metridium senile	($\bar{x}$ ± s)	0.3 ± 0.6	0.6 ± 1.3	-	-
	(no./m^2)	0.13	0.1	-	-
Ptilosarcus gurneyi	($\bar{x}$ ± s)	0.3 ± 0.5	0.2 ± 0.4	-	-
	(no./m^2)	0.13	0.04	-	-
ARTHROPODA - Crustacea					
Balanus rostratus,	($\bar{x}$ ± s)	0	1.0 ± 1.0	-	-
patches	(no./m^2)	0	0.2	-	-
Chionoecetes bairdi	($\bar{x}$ ± s)	0.1 ± 0.2	0.4 ± 0.9	-	-
	(no./m^2)	0.02	0.1	0.1	-
Labidochirus	($\bar{x}$ ± s)	0	2.8 ± 2.5	-	-
splendescens	(no./m^2)	0	0.6	-	-
Pagurus capillatus	($\bar{x}$ ± s)	0	0.8 ± 1.3	-	-
	(no./m^2)	0	0.2	-	-
Pugettia gracilis	($\bar{x}$ ± s)	0.1 ± 0.2	0	-	-
	(no./m^2)	0.02	0	-	-
Telmessus cheiragonus	($\bar{x}$ ± s)	0.1 ± 0.2	0	-	-
	(no./m^2)	0.02	0	-	-
MOLLUSCA - Gastropoda					
Neptunea lyrata	($\bar{x}$ ± s)	0.1 ± 0.3	0.2 ± 0.4	-	-
	(no./m^2)	0.04	0.04	-	-
Oenopota spp	($\bar{x}$ ± s)	-	-	-	2.3 ± 1.5
	(no./m^2)	-	-	-	9.1
CHORDATA - Pisces					
Cottidae, unid	($\bar{x}$ ± s)	0	0.4 ± 0.9	-	-
	(no./m^2)	0	0.1	-	-
Lepidopsetta bilineata	($\bar{x}$ ± s)	0.2 ± 0.5	0	-	-
	(no./m^2)	0.1	0	-	-
Pleuronectiformes, unid	($\bar{x}$ ± s)	0.1 ± 0.2	0.8 ± 0.4	-	-
	(no./m^2)	0.02	0.2	-	-
Fish, unid. elongate	($\bar{x}$ ± s)	0.1 ± 0.2	0	-	-
	(no./m^2)	0.02	0	-	-
Quadrat Size (m):		0.5 x 5	0.5 x 10	0.5 x 50	½ x ½
No. of Quadrats:		18	5	1	11

TABLE 14 RECONNAISSANCE SURVEY FROM MUD BAY, BASE OF HOMER SPIT; 30 JUNE 1978

TAXA	Depth (m)[a] 6.1	4.6	1.5
ALGAE - Chlorophyta			
Monostroma sp			X
Spongomorpha sp			X
ALGAE - Phaeophyta			
Alaria taeniata			X
Desmarestia aculeata	S[b]	X	X
Laminaria sp (unid. sporling)	X		
ALGAE - Rhodophyta			
Coralline alga, encrusting	S		
Porphyra sp			X
PROTOZOA			
Diatom film	X	X	
CNIDARIA - Hydrozoa			
Hydrozoa, unid.	X		
CNIDARIA - Anthozoa			
Anthopleura artemisia		C[c]	X
Halcampa decemtentaculata	X		X
Halcampa sp	S		
Metridium senile	C	X	X
Ptilosarcus gurneyi, (juvenile)	C		
NEMERTEA			
Paranemertes sp	X		
ANNELIDA - Polychaeta			
Crucigera zygophora	C		
Maldanidae, unid.	C		
Nereis sp			X
Phyllochaetopterus sp	X		
Phyllodoce groenlandica	X	S	
?Spionidae, unid.	A[d]	A	
ARTHROPODA - Crustacea			
Balanus rostratus alaskanus	X		
Crustacea cont.			
Balanus sp	X		
Caprellidae, unid. (2 - 3 spp)	X		
Crangon sp	X		
Discopagurus sp	S		
Elassochirus tenuimanus	C		
Euphausiacea, unid.	X		
Gammaridea, unid.	X		
Hyas lyrata	X		
Labidochirus splendescens	C	X	
Oregonia gracilis	X		
Pagurus capillatus	C		
Telmessus cheiragonus	C	X	X
MOLLUSCA - Gastropoda			
Admete couthouyi	X		
Aeolidia papillosa	X		X
Boreotrophon pacificus	X		
Coryphella sp	X		X
Mytilus edulis			C
Neptunea lyrata	X	C	
Oenopota alaskensis	X		
O. alitakensis	X		
O. bicarinata	X		
O. bicarinata var. *violacea*	X		
O. incisula	X		
O. solida	X		
O. turricula cf. *rugulata*	X		
O. sp H	X		
O. sp I	X		
O. sp J	X		
Oenopota unid.	X	X	
MOLLUSCA - Pelecypoda			
Macoma sp	X		
Mya spp		X	
Nuculana sp	X		
Pandora filosa	X		
Yoldia sp	X		

TABLE 14 (Continued)

	Depth (m)		
TAXA	6.1	4.6	1.5
ECHIURA			
Echiurus echiurus		X	
ECHINODERMATA - Asteroidea			
Asterias amurensis	X		
Asteroza, unid.	X		
Evasterias troschelii	X		X
Leptasterias hexactis occidentalis			X
L. ?*hylodes*	X		X
ECHINODERMATA - Echinoidea			
Strongylocentrotus drobachiensis	C	C	
ECHINODERMATA - Ophiuroidea			
?*Amphioidia* sp	X	C	
CHORDATA - Tunicata			
Distaplia ? *occidentale*	X		
CHORDATA - Pisces			
Agonus acipenserinus, juvenile		X	
Ammodytes hexapterus		X	
Cottidae, unid.	X	X	

Substrate: Flat mud bottom with boulders scattered sparsely about. Fecal pellets from worms and Echiurids form an unconsolidated slurry at the water-sand interface. Crab tracks common.

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[a] Below MLLW

[b] S = Sparse

[c] C = Common

[d] A = Abundant

From east of the base camp, near the confluence of Cottonwood and Iliamna Bays to directly in front of the base camp, the substrate was sandy mud or sandy, muddy cobble with scattered boulders. No attached macophytes were noted. However, specimens of the kelp *Laminaria saccharina* attached to small rocks were observed drifting along in the tidal currents. Other seaweeds observed in the area included a filamentous brown alga (*Pylaiella littoralis*) and an unidentified filamentous green alga (Appendix O).

Most of the epifaunal forms were associated with small rocks. The main species noted were a barnacle (*Balanus ?rostratus*), an erect, bushy bryozoan (*Caulibugula* sp.), and an unidentified encrusting orange sponge. Common motile forms included the asteroid *Leptasterias polaris acervata* and the crabs *Telmessus cheiragonus* and *Pagurus ochotensis*.

The infauna was dominated by soft shell clams *Mya* spp. and the cockle *Clinocardium nuttallii*, whose densities averaged 3.7 and 2.2 individuals/m^2, respectively (Table 15). Populations of both species were mainly comprised of large adult clams. A burrowing sea anemone *Anthopleura artemisia* was scattered sparsely throughout the area.

Despite the abundance of clams, predators appeared uncommon. In addition to the starfish *Leptasterias*, whitespotted greenling and rock sole were the only other predators noted; they were uncommon. However, numerous excavations measuring about 0.5 m wide by 0.1 m deep were observed scattered around the area. These may have resulted from the feeding activities of sea otters or rays.

West of the base camp, sandy areas with gravel were noted toward the head of the bay. In addition to *Clinocardium* and *Mya*, the clams *Macoma balthica* and *M. ?obliqua*, the echiurid *Bonelliopsis alaskanus* and the ice cream cone worm *Cistenides granulata* were common.

Farther west, the gravel became coarser and more abundant. In this area, algal cover averaged about 30 percent.

TABLE 15 SPECIES COMPOSITION FOR COTTONWOOD BAY SUBTIDAL AREA; 13 JUNE 1978, LESS THAN 1.5 M BELOW MLLW

TAXA			
Mollusca - Pelecypoda			
Clinocardium nuttallii	($\bar{x}$ ± s)	2.4 ± 3.3	-
	(no./m^2)	9.6	1.7
Mya spp	($\bar{x}$ ± s)	2.0 ± 2.0	-
	(no./m^2)	8.0	3.4
Quadrat Size (m^2):		¼	0.5 x 35
No. of quadrats:		5	1

3. The Biological Assemblage at Nordyke Island Channel

A brief dive was made in the channel west of Nordyke Island. At an approximate depth of 6 m, the substrate was an unconsolidated silt with heavy shell debris and small cobble. Heavy encrustations of small to medium-sized *Balanus* and occasional hydroids (*Abietinaria*) were observed on the shell and cobbles.

Between the 6 m and 9.1 m, the substrate graded from mixed silt and cobble to silt; correspondingly, the sessile epifaunal disappeared. No sign of epifaunal forms was observed from 9 m to 12.2 m, although local residents related that tanner crabs are seasonally abundant in the area.

The main indication of infaunal activity was the presence of sparsely distributed mud cones approximately 3 to 5 cm in height. These were probably produced by some large polychaete such as *Nephtys punctata*. The area was visually similar to the shallow subtidal slopes of Port Valdez, where *N. punctata* is abundant (Lees et al. 1979b).

4. The Biological Assemblage at Oil Bay

Reconnaissance dives were made in Oil Bay at depths of 1.2 and 2.7 m below MLLW. The substrate was a fine, silty sand with small ripple marks and moderate organic debris.

The impoverished assemblage comprised mainly of a few species of clams and predators/scavengers. The razor clam was most abundant; its density was about 0.07 siphons/m^2. Although not enumerated, the density of the redneck clam *Spisula polynyma* was probably about the same. The crab *Telmessus* and flatfish were next in abundance with only 0.03 individuals/m^2. Additional species observed included small hermit crabs, crangonid shrimp and gammarid amphipods, butter sole, rock sole, and snake prickleback (Appendix P).

VII. DISCUSSION

A. COMPARISON OF ASSEMBLAGES

The main habitat types examined included kelp and *Modiolus* beds on rocky substrate. In several locations, such as Jakolof Bay, these assemblages overlapped. Based on appearance and species composition, these assemblages fall into three geographically distinct groups, namely, 1) southern Kachemak Bay, 2) northern Kachemak Bay and 3) western Cook Inlet assemblages. Some of the major species characterizing each assemblage are listed in Table 16 and their distribution patterns indicated. The three assemblages can be distinguished on the basis of the composition and structure of both the macrophyte and the epifaunal components.

The southern Kachemak Bay assemblage was characterized by consistent development of a lush, fairly dense kelp bed consisting of both a canopy and an understory, a low diversity, poorly-developed epifaunal component, and a diverse, low-density predator/scavenger component (Table 16). Development of the canopy usually did not extend past a depth of about 12 m but the understory kelps extended past 21 m where appropriate substrate was available. The canopy was formed by *Alaria fistulosa* in areas of high current velocity and by *Nereocystis* in areas of lower velocity. Although both *Laminaria* and *Agarum* were frequently mixed in the understory, *Laminaria* was most successful in shallow, well-lighted situations and *Agarum* extended out to greater depths; *Laminaria* was more common and better developed in turbulent areas with good circulation.

The sedentary invertebrate component, mostly comprising suspension feeders, was generally poorly developed. The only two commonly observed species were the large fleshy bryozoan *Flustrella gigantea* and the butter clam *Saxidomus giganteus*. Diversity was higher at the two sites more exposed to tidal currents, but only at Jakolof Bay did the density or standing stocks of suspension feeders approach that observed at Archimandritof Shoals or Troublesome Creek. In fact, Jakolof Bay was a

TABLE 16

DOMINANT SPECIES IN MAJOR ROCK BOTTOM SUBTIDAL ASSEMBLAGES IN LOWER COOK INLET

	Southern Kachemak Bay			Northern Shelf of Kachemak Bay			West Side of Cook Inlet		
	Seldovia Point	Barbara Bluffs	Jakolof Bay	Archimanritof Shoals	Bluff Point	Troublesome Creek	Knoll Head Lagoon	White Gull Island	Black Reef
Kelps									
Surface canopy									
Nereocystis leutkeana	A(12)*	A	A	C(19)					
Alaria fistulosa	A(12)		A		C(12)	C			
Understory									
Agarum cribrosum	A(21)	A	A	C(13)	C(16)	C(14)	C(5)	C(3)	S(4)
Alaria spp. (not fistulosa)	Intertidal	Intertidal	Intertidal				A(2)	C(2)	S(2)
Laminaria groenlandica	A(20)	A	A	C(10)	C(12)	C(14)	C(4)	C(3)	S(2)
Maximum depth of kelps (m)	21	>14	>12	13	16	15	5	3	4
Sedentary Invertebrates									
Flustrella gigantea	A	C	P	C	A	C	P		
Microporina borealis	C				C	S			
Mycale spp.	C			C	P	C	C	C	C
Saxidomus giganteus	C	P	A	C-A	S	A			
Modiolus modiolus			A	A	C	C	A	S	S
Potamilla neglecta			A	A			C	C	
Halichondria panicea	S				S	A	P	C	C
Balanus rostratus				C	C		S-C	C	C
Dendrodoa pulchella								A	A
Costazia ?surcularis							C	A	A
Metridium senile	S		C		S	S		S	S
Cucumaria miniata			S	S	C	A		C	
C. fallax				S	C	A			
Bidenkapia spitsbergensis					P			C	C
Dendrobeanica murrayana				C	S			C	
Motile Invertebrates									
Evasterias troschelii	S		A		C	S			
Dermasterias imbricata			A			S			
Pycnopodia helianthoides	C	S	A			S			
Orthasterias koehleri	C	P	C			S			
Henricia leviuscula	C		C		S	S			P
Leptasterias polaris acervata				C	S	C	C	P	P
Solaster stimpsoni	S		C	S	S	S		P	
Crossaster papposus	C	P	C	C	C	S	C	P	P
Henricia sanguinolenta	S	P	A		C	C	C	C	P
Fusitriton oregonensis	C		A	C	C	C	C	S	P
Neptunea spp.				C	C	C	S	S	P
Buccinum glaciale				S	S	S	S	S	P
Beringius kennicotti				S	S		S	S	P
Tonicella spp.	C	P	C	C	C	C	C	S	P
Strongylocentrotus drobachiensis	C	C	A	A	C	A	S	S	P

A=Abundant; C=Common; S=Sparse; P=Present

*Parenthetic numbers represent maximum depth of occurrence in this area location where the kelp and Modiolus assemblages strongly overlapped. However, although Modiolus and several other suspension feeders had extremely robust populations, suspension-feeder diversity was not notably high.

The micrograzers Tonicella spp. and the macrograzer Strongylocentrotus drobachiensis were generally common to abundant.

The predator/scavenger component of the southern Kachemak Bay assemblage was generally diverse but, except at Jakolof Bay, exhibited low density. Sea stars were the dominant motile predatory invertebrates. Twelve species have been noted in southern Kachemak Bay; nine of these were common to abundant in subtidal habitats. Sea star densities and standing stocks at Jakolof Bay were among the highest observed in Cook Inlet or Prince William Sound. Fusitriton oregonensis, the only large predatory snail present, was generally common, but densities recorded at Jakolof Bay were quite high. Fish assemblages were fairly well developed; species richness and abundance were moderately high (Rosenthal and Lees 1979).

The northern Kachemak Bay assemblage was characterized by moderate development of a kelp bed consisting of a very spotty, thin canopy and a moderate understory, but well-developed assemblages of sedentary invertebrates and predator/scavengers (Table 16). Canopy development, seldom extending past 10 m, was spatially patchy and temporally inconsistent. Although understory kelps were observed out to 16 m, actual beds were generally not observed deeper than 12 m. Species composition and habitat characteristics of the surface canopy and understory were the same as described for the southern Kachemak Bay assemblage.

The sedentary invertebrate component, mostly comprising suspension feeders, was generally well developed and highly robust; it had high diversity and standing stocks. Species diversity and standing stocks were among the highest seen, at least in Alaska. Some of the more important species included Modiolus, Flustrella, Saxidomus, the sponge Mycale and the sea cucumbers Cucumaria miniata and C. fallax. Several species, e.g., Modiolus, *Saxidomus*, the sabellid worms *Potamilla* and *Schizobranchia* and *C. miniata*, formed dense, compact beds of large size. Often these beds were a mixture of two or more species. For instance, at several sites on Archimandritof Shoals, the bottom was a carpet of *Potamilla* tubes overlaying a dense mixed bed of *Modiolus* and *Saxidomus*. Other suspension feeders important at several locations included the arborescent, calcified bryozoans *Microporina borealis* and *Dendrobeania murrayana*, the sponge *Halichondria panicea*, and the barnacle *Balanus rostratus alaskanus*. The development of this component at Troublesome Creek was astounding, and could not be reflected accurately in Table 16 because of the large number of unidentified species, especially sponges, hydroids, tunicates and bryozoans, observed there.

The micrograzers *Tonicella* spp and the sea urchin *S. drobachiensis*, a macrograzer, were generally quite abundant. It has been hypothesized that the poor development of the algal assemblage is due in part to overgrazing, particularly by sea urchins and, in part to low light levels resulting from turbidity (Rosenthal and Lees 1976). The fact that most sea urchins are exposed rather than cryptic indicates that the population is mainly browsing on attached algae (Lees 1970). This condition probably results from a relative undersupply of drift material.

The predator/scavenger component of this assemblage was diverse and often, the density of these animals was high. Again, sea stars dominated the component but snails and crustaceans were important. Although about fifteen species of sea star were recorded from the northern shelf, only five were considered common (Table 16). Most important among these seemed to be *Leptasterias polaris acervata*, *Crossaster* and *Henricia sanguinolenta*. Conspicuously sparse were *Evasterias*, *Pycnopodia* and *Orthasterias*. Important predatory snails included *Fusitriton*, and *Neptunea* spp. Important crustaceans included the crabs *Hyas*, *Oregonia* and *Pugettia* and the hermit crabs *Pagurus ochotensis*, *P. beringanus*, *P. trigonocheirus*, *Elassochirus gilli* and *E. tenuimanus*. Furthermore, this is probably one of the more important nursery areas for king crab in the southeastern quadrant (Sundberg and Clausen 1977).

The western Cook Inlet assemblage was characterized by poor or no development of a kelp bed assemblage, no surface canopy species, a diverse, well-developed but thin veneer of sedentary invertebrates, and a moderately developed predator/scavenger component (Table 16). The understory species, *Alaria praelonga*, *A. taeniata*, *Agarum* and *Laminaria*, were observed to a maximum depth of about 5 m, but were sufficiently dense to form beds only to about 3 m. The depth limitation appeared to be imposed by turbidity as suitable substrate was observed to a depth of 15 m in several locations. However, most rocky surfaces were covered with a moderate dusting of sediments.

The sedentary invertebrate component, although diverse and covering a large proportion of the available rock, generally formed only a thin veneer over the surface. Standing stocks appeared low. The only exceptions were in the few locations where *Modiolus* and *Potamilla* beds developed considerstanding stocks (Table 11). Generally, these were not observed below a depth of about 5 m, occurring in or just below the kelp understory. The most important taxa below the kelp beds included the barnacle *Balanus rostratus alaskanus*, several encrusting, digitate, and laminate bryozoan species, several sponges, including *Mycale* and *Halichondria*, and some tunicates, including the social form *Dendrodoa pulchella* and some species of *Synoicum* (Table 16). The combination of the barnacles, encrusting digitate and laminate bryozoans and the silt gave this asseblage a dirty, drab, jagged appearance. Generally, encrusting forms such as bryozoans and tunicates were absent in the kelp bed, probably as a consequence of scour by ice and algae.

The microherbivorous chitons *Tonicella* spp. and the macroherbivorous sea urchin *Strongylocentrotus drobachiensis*, although frequently observed, were generally less abundant than on the east side of the inlet. This is probably a response to the small quantities of macrophytes available.

The predator/scavenger component of this assemblage was fairly diverse, but densities of most species were low. Sea stars and snails were the most important invertebrate taxa observed in this component. Of the eight species of starfish observed, only three were common. These were Leptasterias polaris acervata, Crossaster papposus and Henricia sanguinolenta; Solaster stimpsoni and L. ?hylodes were observed frequently. Most of the sea star species observed were brooders. Four species of predatory snail were observed commonly but densities appeared low (Table 16). The fish assemblage appeared poorly developed in rocky areas on the west side of the inlet; even on habitat that appeared excellent, fish diversity and density was low (Rosenthal and Lees 1979).

The strongest differences among these were between the Kachemak Bay assemblages and the west side assemblage. Although many of the species observed on the west side also were found in Kachemak Bay, especially at Archimandritof Shoals and Bluff Point, the absence there of numerous species dominant in Kachemak Bay and the abundance of numerous species more characteristic of the Bering and Beaufort Seas acted to create a dramatically different appearance. A comparison among the bryozoans reported for Point Barrow and the three assemblages in lower Cook Inlet illustrates this similarity (Table 17). In sharp contrast, the southern Kachemak Bay assemblage includes 20 percent of the bryozoan species dominating at Point Barrow whereas the west side assemblage includes over 65 percent. This is particularly important because most of thse species are erect forms, i.e., either bushy, foliaceous, digitate or head-forming, and therefore contribute a great deal more to biomass and habitat complexity than encrusting species.

Despite the contribution of bryozoans, the suspension-feeding component was most strongly developed in Kachemak Bay, at Jakolof Bay and along the northern shelf. In fact, these areas supported the most diverse, productive suspension-feeding assemblages observed by the authors in the eastern Pacific Ocean. Estimates of total standing stocks or production of suspension feeders have not been made, but would obviously be very high. However, it is probable that standing stocks and productivity of suspension feeders are higher on the west side than at Seldovia Point or Barabara Bluffs, and probably in other typical kelp bed assemblages.

TABLE 17

COMPARISON OF BRYOZOAN ASSEMBLAGES FOR COOK INLET AND POINT BARROW

Dominant Bryozoans off Point Barrow*	Southern Kachemak Bay	Northern Kachemak Bay	West Side of Inlet Kamishak Bay	Other
Eucratea loricata		x	x	xx
Carbasea carbasea		x	x	x
Terminoflustra membranaceo-truncata	x	x	x	x
Bidenkapia spitsbergensis		x	x	x
Tegella magnipora				x
Tricellaria erecta		?	?	
Dendrobeania murrayana	x	x	x	
Hippothoa hyalina			x	x
H. divaricata				
H. expansa				
Stomachetosella sinuosa				
S. distincta				
Ragionula rosacea				
Pachyegis princeps			x	
P. brunnea			x	
Porella compressa		x	x	x
Rhamphostomella gigantea				
R. bilaminata			?	?
Costazia nordenskjoldi			?	
C. surcularis			x	x
C. ventricosa			?	
Myriozoum subgracile		x		
Alcyonidium polyoum		x	x	x
A. disciforme	?			
A. pedunculatum	x	x	x	x
A. enteromorpha			x	x
Flustrella corniculata	x	x	x	x
F. gigantea	x	x	x	x
Bowerbankia gracilis				

*Based on MacGinitie (1955)

Development of the predator/scavenger components bears a direct correspondence to development of the epifaunal component. Densities of a wide variety of predator/scavengers were high at locations with well-developed suspension-feeding components, i.e., Troublesome Creek and Jakolof Bay. A strong qualitative difference in the sea star and snail fauna was obvious as well. Most of the sea stars observed on the west side of the inlet are thought to brood their eggs, rather than produce planktonic larvae. Nearly all of these species were reported from Point Barrow (MacGinitie 1955). Furthermore, only ten of the eighteen species found in Kachemak Bay were observed on the west side of the inlet and five of the missing species are dominant predators in some part of Kachemak Bay.

The conspicuous differences between development of the kelp assemblages were also quite important. The presence of a surface canopy and extension of the kelp assemblage down to at least 12 m in Kachemak Bay (vs. only 4 m on the west side of the inlet) mean that, in addition to influencing the appearance, primary productivity is much higher on rocky habitats in Kachemak Bay than on the west side of the inlet.

B. BIOLOGY OF MODIOLUS

A comparison of the size-frequency histograms for Modiolus indicates the occurrence of two general population types. Type 1 populations comprised significant quantities of both young and old individuals and Type 2 populations were almost totally dominated by old animals. However, nearly all populations were strongly dominated by older adult animals and it appears that, in contrast to the massive annual recruitment observed in Mytilus, annual recruitment is generally small and unpredictable for Modiolus; a population with a large proportion of juveniles was never observed. Size (and age) structure and development of the population in terms of biomass and density suggest that Type 1 populations are the most stable or viable, and that the areas in which they occur are presently the most suitable for Modiolus. The paucity of juveniles suggests that Type 2 populations are senescent or predator-dominated.

The importance of Modiolus in lower Cook Inlet cannot be assessed without better knowledge of its distribution. However, based on anecedotal reports from several halibut fishermen and other scientists (Driskell and Lees 1977; Bouma et al. 1978), Modiolus is common in 25 to 50 m of water on the northern shelf of Kachemak Bay, along the east side of inlet between Anchor Point and Ninilchik, and east of Chinitna Bay. Some of these areas are favored by commercial halibut fishermen, implying that halibut aggregate there. This is understandable if crustaceans are as common in deeper Modiolus beds as was observed off Bluff Point; crustaceans constitute a sizable proportion of the diet of halibut. Furthermore, migration "routes" of king and tanner crabs seem to pass through several suspected or known Modiolus beds in Kachemak Bay.

In any event, in terms of biomass and secondary production, Modiolus must be among the most important species on subtidal rocky or mixed coarse substrates. No other subtidal suspension feeder has been observed to contribute as much to standing stocks over as large an area, or is suspected of having such high productivity.

C. TROPHIC STRUCTURE OF INVERTEBRATE ASSEMBLAGES ON ROCKY SUBSTRATES IN LOWER COOK INLET

A comparison of the generalized food webs constructed for the three major shallow water rock bottom assemblages in lower Cook Inlet indicates basic similarity but some important differences (Figures 13 and 14). The two assemblages from Kachemak Bay, in particular, are quite similar. The main differences are probably quantitative; kelp assemblages on the south side of Kachemak Bay produce greater quantities of plant materials (Lees et al. 1979), thus contributing more energy to detrital reserves in other locations (e.g., deep benthic assemblages, sand beaches or mud flats). On the other hand, suspension-feeding and predator/scavenger components on the north side of Kachemak Bay are better developed (Table 16; Rosenthal and Lees 1976; Lees and Houghton 1977). Both assemblages contribute considerable quantities of plant, suspended and dissolved organic material to the consumer

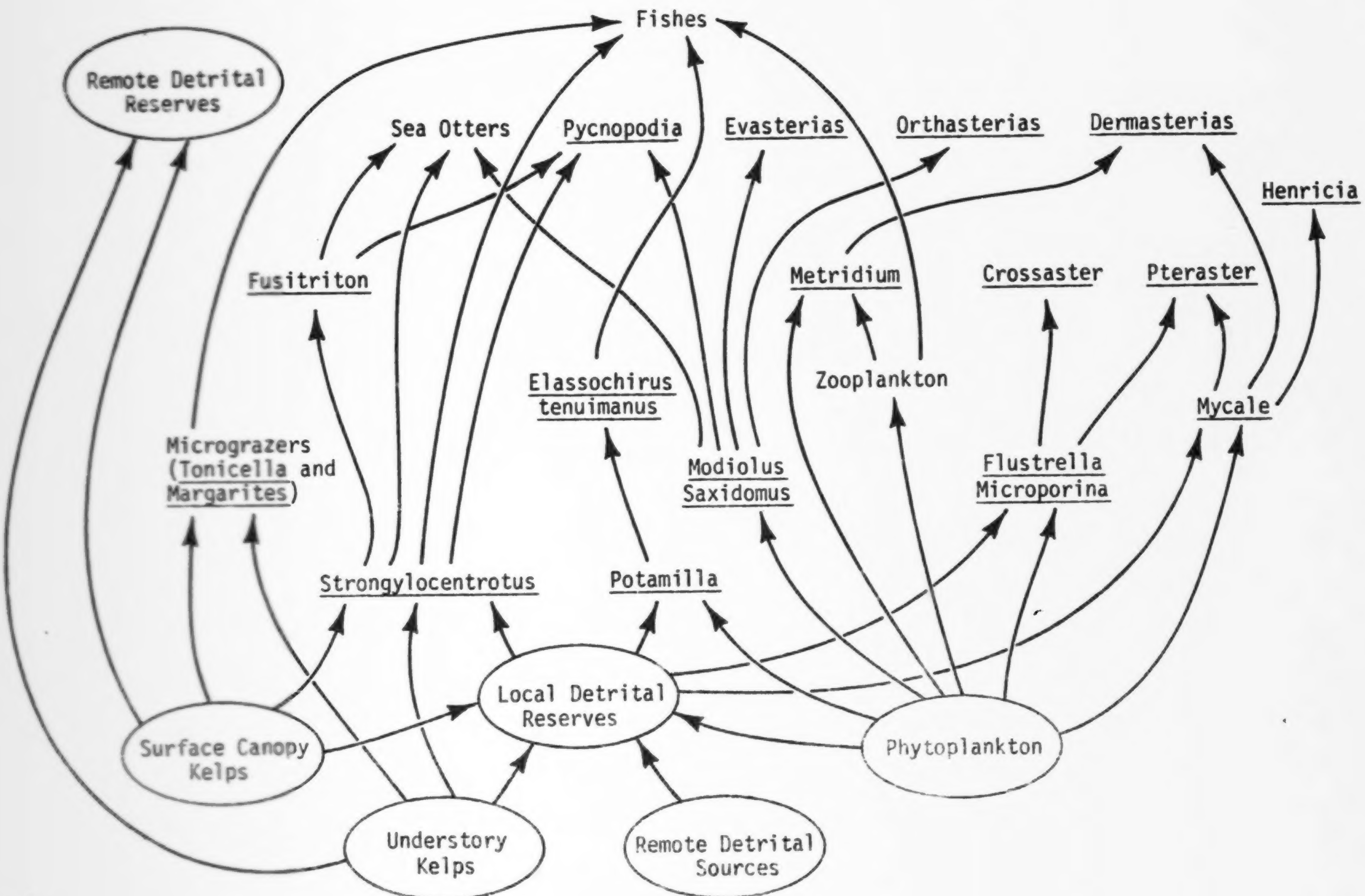
Fishes
Remote Detrital Reserves
Sea Otters
Pycnopodia
Evasterias
Orthasterias
Dermasterias
Henricia
Fusitriton
Metridium
Crossaster
Pteraster
Elassochirus tenuimanus
Zooplankton
Mycale
Micrograzers (Tonicella and Margarites)
Modiolus Saxidomus
Flustrella Microporina
Strongylocentrotus
Potamilla
Local Detrital Reserves
Surface Canopy Kelps
Phytoplankton
Understory Kelps
Remote Detrital Sources

FIGURE 13

GENERALIZED FOOD WEB FOR THE SHALLOW SUBTIDAL ASSEMBLAGE IN THE SOUTHERN KACHEMAK BAY

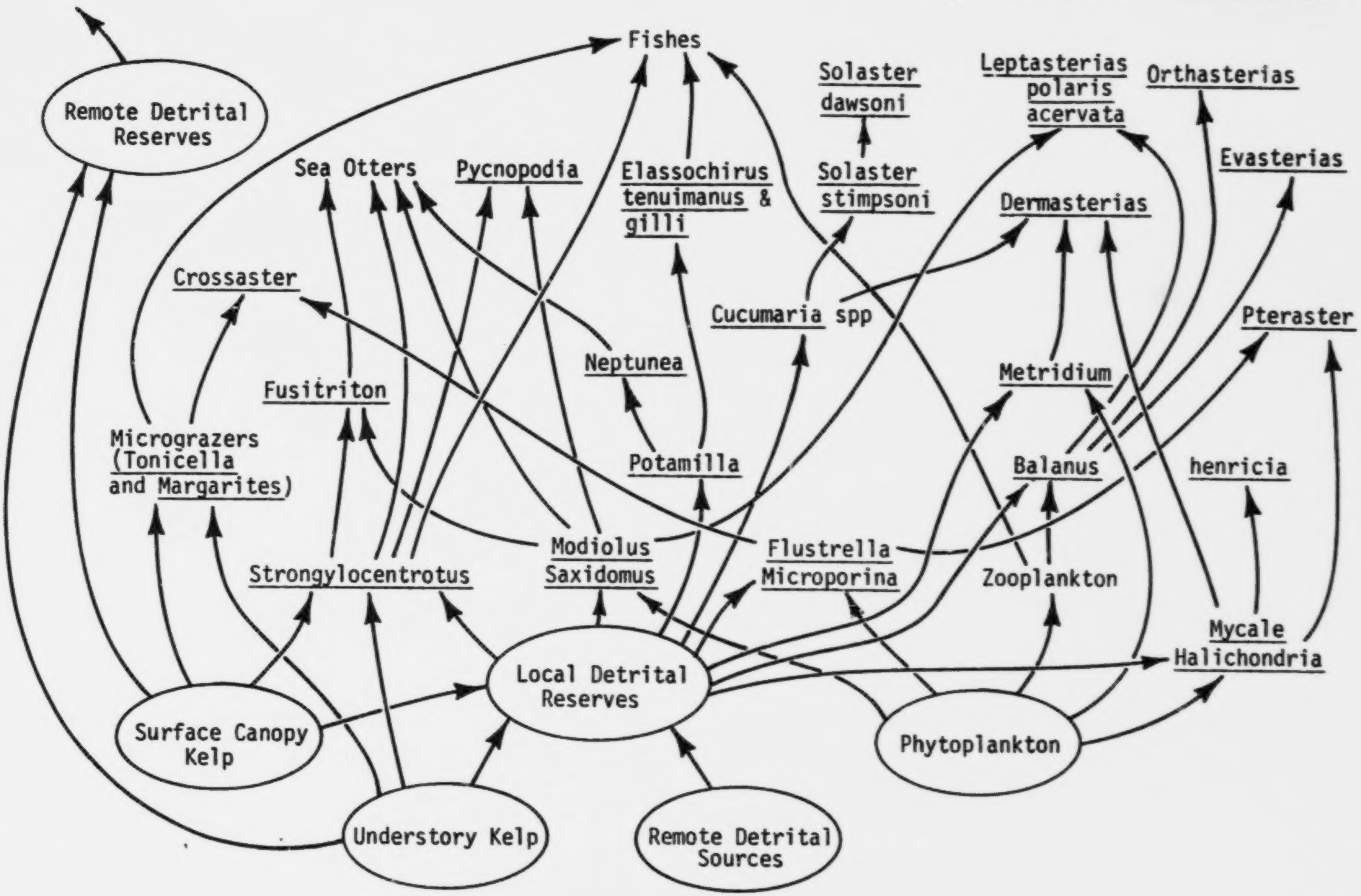
Fishes
Solaster dawsoni
Leptasterias polaris acervata
Orthasterias
Remote Detrital Reserves
Sea Otters
Pycnopodia
Elassochirus tenuimanus & gilli
Solaster stimpsoni
Evasterias
Dermasterias
Crossaster
Cucumaria spp
Pteraster
Neptunea
Metridium
Fusitriton
Micrograzers (Tonicella and Margarites)
Potamilla
Balanus
henricia
Modiolus Saxidomus
Flustrella Microporina
Strongylocentrotus
Zooplankton
Mycale Halichondria
Local Detrital Reserves
Surface Canopy Kelp
Phytoplankton
Understory Kelp
Remote Detrital Sources

FIGURE 14

GENERALIZED FOOD WEB FOR THE SHALLOW SUBTIDAL ASSEMBLAGE ON THE NORTHERN SHELF OF KACHEMAK BAY organisms of lower Cook Inlet. In both cases, the suspension-feeding assemblage probably depends very heavily on organic materials of marine origin. However, the proportion of terrigenous materials in the water mass is probably substantially higher on the north side of Kachemak Bay. Because of prevailing currents and productivity patterns, the quantity of organic debris available to suspension feeders is probably higher on the northern shelf than on the southern side, except at sites like Jakolof Bay. Water passing through Kachemak Bay picks up organic materials from the estuaries, rivers and the high phytoplankton production in Kachemak Bay. It also picks up a substantial quantity of suspended sediments in its progress through the bay. These conditions promote microbial activity and flocculation. These waters move rapidly across the northern shelf of the bay, providing great quantities of suspended organic matter to the suspension feeders living there. The differences in the development of kelp assemblages are also important in explaining the differences in the development of the suspension-feeding assemblages. The heavy growth of kelps along much of the south side of Kachemak Bay substantially decreases the current velocity in the kelp beds; this is particularly noticeable in the understory near the dense kelp bed between Seldovia and Barabara Point where tidal currents are greatly reduced. The effect of this on suspension feeders is to reduce the amount of food to which they are exposed. This factor and the relative paucity of organic matter in the impinging oceanic water mass are probably the major factors responsible for the poor development of the suspension-feeding assemblage on the south shore of Kachemak Bay. The extraordinary development of suspension feeders at Jakolof Bay (>10 kg tissue/m^2) is probably due to its proximity to the rich, estuarine embayment, the strong tidal currents resulting from the constricted entrance, and fact that the kelp bed is not large enough to produce an effective reduction in current velocity. On the northern shelf, however, current velocity is essentially unimpeded by the poorly-developed, scattered kelp beds (personal observation). Thus, the nutrient-rich waters leaving Kachemak Bay are more directly in contact with the suspension feeders and exposure to food particles is greater.

Despite the basic similarity between the food web for the west side of the inlet (Figure 15) and those for Kachemak Bay, some strong qualitative

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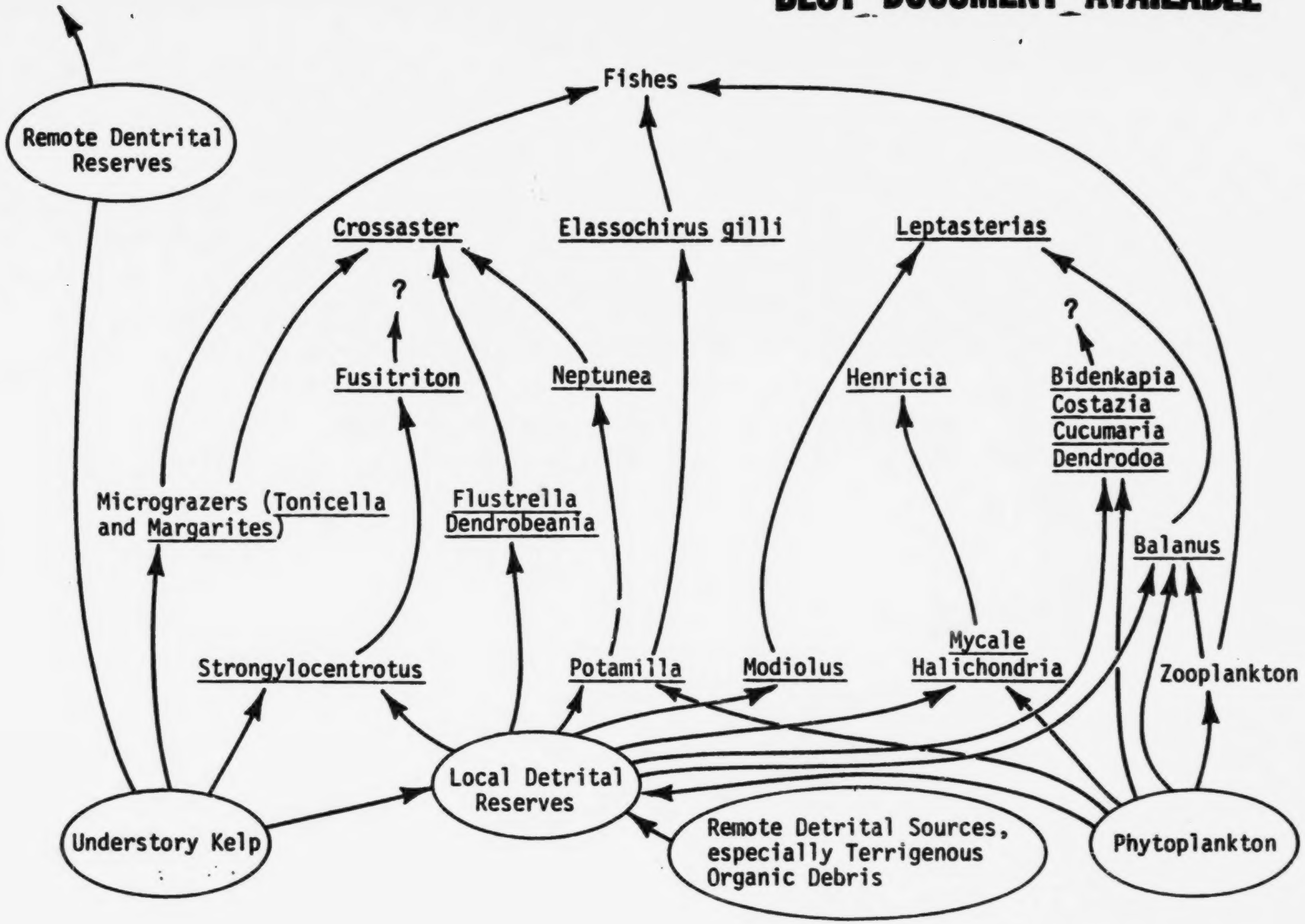
Fishes
Remote Dentrital Reserves
Crossaster
Elassochirus gilli
Leptasterias
?
Fusitriton
Neptunea
Henricia
?
Bidenkapia
Costazia
Cucumaria
Dendrodoa
Micrograzers (Tonicella and Margarites)
Flustrella
Dendrobeania
Balanus
Strongylocentrotus
Potamilla
Modiolus
Mycale
Halichondria
Zooplankton
Local Detrital Reserves
Understory Kelp
Remote Detrital Sources, especially Terrigenous Organic Debris
Phytoplankton

FIGURE 15

GENERALIZED FOOD WEB FOR THE SHALLOW SUBTIDAL ASSEMBLAGE ON THE WEST SIDE OF LOWER COOK INLET and quantitiative differences are apparent. The contribution of the kelp assemblage to remote detrital reserves is much smaller; probably a greater proportion of the available detrital material is terrigenous. This is a consequence of the numerous rivers, especially the Susitna River, which also contributes considerable fresh water to the water mass of Cook Inlet. Also, based on the generally poor development and limited standing stocks of the suspension-feeding assemblages observed on the west side of the inlet, the quantity of available detritus is probably considerably smaller than on the northern shelf in Kachemak Bay. Larrance and Chester (1979) reported that phytoplankton contribution to the benthos was lower in Kamishak Bay. Both density and species richness of predator/ scavenger component, including fishes, are generally rather impoverished on rocky substrates.

The food webs exclude the relationships and effect of several important groups within the various trophic levels because of inadequate information. The effects of migratory crustaceans such as king and dungeness crabs have not been considered because they have not been encountered in the study areas. However, commercial fishing activities suggest that these species pass through some of the areas examined, especially along the northern shelf of Kachemak Bay. It is probable that they feed on at least some of the dominant suspension feeders listed. Fishes have been considered by other studies (Rosenthal and Lees, 1979; Blackburn, 1977) and so were omitted from this discussion. However, it should be noted that fish on rocky habitats are important consumers of crustaceans such as amphipods, isopods, shrimp, small crabs and hermit crabs, and small snails (Rosenthal and Lees 1979). Marine birds have also been examined in other projects and so have not been discussed in detail. Generally, diving birds are reported to concentrate on small molluscs, crustaceans and fishes (Sanger, Jones, and Wiswar 1979, David Erikson, personal communication, Paul Arneson, personal communication). Many of the inshore birds feed on benthic forms of fish and crustaceans. Finally, a number of the less conspicuous predators and scavengers have not been examined or considered. The influence of micro-grazers such as limpets and chitons is not clear in these habitats but may be substantial in the determination of algal development (Smith, 1968, Nelson-Smith, 1972). The influence of small predatory snails, crustaceans and polychaetes is unknown in these habitats; because of their abundance, they could be very important as predators on larval, juvenile or young forms of the dominant species, and could be important to energy flow as well as species composition.

D. POTENTIAL FOR IMPACT FROM OCS OIL AND GAS EXPLORATION, DEVELOPMENT, AND PRODUCTION

The susceptibility of the assemblages described above to deleterious impacts from OCS oil and gas exploration, development, and production activities depends primarily upon the probability of exposure (i.e., the vulnerability of the assemblages), and the sensitivity of the assemblages and their component organisms in the event that they are exposed to oil or dispersant contamination. The probability of exposure has been predicted in oil spill trajectory analyses for lower Cook Inlet conducted by Dames & Moore (1979). Although some data are available for some of the species considered important in the three main rocky subtidal assemblages, in fact, very little is known directly and predictions must be based mainly upon the physical characteristics of the habitats, apparent degree of development, productivity and stability of the assemblages, and inferences of the sensitivity of the organisms comprising the assemblages based on information for similar species. The whole procedure is highly speculative.

1. Vulnerability to Exposure

Oil spill trajectory models indicate that shorelines with the greatest risk of exposure in the event of an oil spill occur 1) between Iliamna Bay and Chinitna Bay, on the west side of lower Cook Inlet, 2) between Dangerous Cape and Cape Elizabeth, in Kennedy Entrance, 3) on the Barren Islands, and, 4) on Shuyak Island, at the north end of the Kodiak Island archipelago (Dames & Moore 1976; 1979). Exposure at these sites would generally occur in one to three days of a spill, and the annual probability of exposure generally is from 3 to 6 percent, assuming the occurrence of a single spill per year for any one of the hypothetical spill sites. Additional areas of concern are near Harriet Point, Anchor Point and on the NE quadrant of

Augustine Island. An important finding of the 1979 study was that the trajectories contacted the Chugach Islands and Shuyak Island, and "suggest the possibility of exposure on the eastern side of the Kenai Peninsula as well as Kodiak Island" (Dames & Moore 1979).

Based on the tendency of spilled oil to attach to suspended sediment particles (Kolpack 1971), turbidity patterns would cause a greater proportion of the spilled oil to come into contact with the benthos in Kamishak Bay and on the northern side of Kachemak Bay (NAS 1975). As a consequence, the benthic assemblages on the west side of lower Cook Inlet have a greater vulnerability to exposure than in Kachemak Bay, where the northern shelf assemblages are at greatest risk. Although shoreline impact is predicted to be critical in Kennedy Entrance and on the north shore of Shuyak Island, the high degree of turbulence and generally great water clarity would tend to minimize the amount and duration of contact.

2. Sensitivity to Oil

a. Southern Kachemak Bay Assemblage

The southern Kachemak Bay subtidal assemblage is dominated heavily by kelps, which are generally quite tolerant to exposure to crude oils (Nelson-Smith 1972; Smith 1968; Straughan 1972). Furthermore, Smith (1968) observed that the kelp understory may impart some protection to the epifauna. The red algae that do occur might be seriously effected, however, (Smith 1968). Herbivores moderately abundant in this assemblage, are fairly sensitive to oil exposure (Rice et al. 1979; Smith 1968; Nelson-Smith 1972). Thus, in the event of a large spill, moderate damage to the herbivore component might occur. The suspension-feeding and predator/scavenger components although probably fairly sensitive to oil exposure, are generally poorly developed except at Jakolof Bay. Thus, damage to the assemblage would be slight, except at Jakolof Bay. At sites like Jakolof Bay, however, suspension-feeding and predator/scavenger components are exceptionally well-developed and complex and, although little is known about the sensitivity of the species comprising the components, subtidal clams, starfish, and snails may be moderately sensitive (Rice et al. 1979; Smith 1968; Nelson-Smith 1972) and thus considerable damage could occur.

Recovery times in these systems would vary. The initial results in a "standard" kelp bed, because of a reduction in grazing pressure and reduced competition for space beetween suspension-feeders and kelps, would probably lead to increased plant production. Although development of the herbivore component in this assemblage is substantially less complex than in the one described by North et al. (1964), recruitment appears to be slow in the echinoid populations, which dominate many areas. Therefore, recovery of the herbivore populations probably could require between five and ten years.

At sites like Jakolof Bay, where herbivore, suspension-feeding and predator/scavenger components are well-developed, disruption and outright damage might be extensive and recovery might require many years, especially if dispersants were used. Damage to the herbivore component would result in greater development of the kelp assemblage. Damage to the suspension-feeding component also might result in greater development of the kelp because of reduced consumption of spores, as suggested by North et al. (1964), and increased availability of suitable substrate. Even if the predator/scavenger component were not damaged directly by oil contamination, it probably would be devastated by the loss of its prey resources, and its recovery would depend upon the recovery of those components. Size structures of several of the dominant species indicate that their populations are dominated by adults, that successful recruitment is sporadic. Thus, recovery would depend not only upon the time required for the habitat to recover to a point at which the natural species could recolonize, but also upon the occurrence of successful recruitment. This could be complicated if the predator/scavenger populations are damaged less by oil than the suspension feeders and herbivores.

We have recently observed the occurrence of an apparently analogous situation in intertidal and shallow subtidal regions of Prince William

Sound. The Great Earthquake of 1964 uplifted large tracts of gravel/cobble habitat and killed, in place, dense populations of large-sized clams (Baxter 1971). Thus, it is still possible to examine the density and size structure of the pre-quake populations. Densities and size structures of pre-earthquake populations, examined in many uplifted areas during the summer of 1979, indicate that, although limited recruitment is occurring in these areas, attainment of the previous high densities and large average shell size has not occurred and may be strongly limited by the large populations of mobile predators such as sea otters and sea stars which were not as severely damaged by the earthquake. Although 15 years have passed since the Great Earthquake, it appears that many more will pass before these populations have recovered.

b. Northern Kachemak Bay Assemblage

The kelp component of the northern Kachemak Bay assemblage exhibits moderate development whereas the suspension-feeding component is moderately to highly developed. Herbivores, especially sea urchins, and predator/scavengers are also common. Based on these patterns, it appears that a large oil spill in this area could have a severe effect upon the appearance and productivity of the assemblage. The kelp assemblage probably would not be extensively harmed by exposure to either crude oil or dispersants. However, the herbivore, suspension-feeder and predator/scavenger components probably would exhibit moderate to severe damage. Because the overlying waters in this area are characteristically somewhat turbid, a substantial proportion of the oil entering the area would be adsorbed and enter the water column; the turbulence characteristic of the area would then tend to bring much of this oil into contact with that substrate and the benthic animals. This is of special concern since this area appears to be an important nursery area for king crab (Sundberg and Clausen 1977). Experiments by Rice et al. (1979) suggest that some of these benthic forms such as king crab may be moderately sensitive to damage from crude oil and that subtidal animals are more sensitive than their intertidal counterparts. Crustaceans, which constitute a large proportion of the predator/scavenger component of this shelf, and, to a lesser extent, sea stars, appear quite sensitive to oil contamination (Smith 1968; Rice et al. 1979; Nelson-Smith 1972; NAS 1975). As a consequence of the damage to the herbivore and suspension-feeding components, development of the kelp assemblage probably would improve because of decreased competition for space and grazing pressure; thus primary production might increase. However, the loss of the robust suspension-feeding component probably would result in reduced secondary production for a period of time.

Recovery time would probably be substantial. North et al. (1964) reported that the subtidal epifaunal assemblage or a kelp bed was far from recovery seven years after a catastrophic spill of diesel oil. Mann and Clark (1978) estimated recovery of a bed assemblage kelp destroyed by sea urchins off Nova Scotia would require at least ten to twenty years. Since many of the important epifaunal animals live at least that many years, and recruitment of many of them appears quite sporadic, it seems probable that recovery from serious disruption might require at least ten to twenty years.

c. Assemblage from the West Side of Lower Cook Inlet

If the observation is true that a kelp understory provides some protection to the epifauna (Smith 1968), then the subtidal epifaunal assemblages on the west side of the inlet are structurally more exposed and vulnerable than those in Kachemak Bay or in Kennedy Entrance because of the sparseness or absence of the understory kelps. Only in the intertidal and very shallow subtidal zone is the kelp assemblage present on the west side of Cook Inlet. In those habitats, although the herbivore component generally is poorly developed, kelp development is strongly limited by physical factors such as ice scour and turbidity. The suspension-feeding component is moderately developed in the subtidal zone, but composition and appearance differs substantially between very shallow and somewhat deeper substrates. The very shallow levels often support beds of *Modiolus* and the sabellid polychaete *Potamilla* whereas the deeper areas are dominated by thin, jagged, drab encrustations of barnacles, bryozoans, sponges, and tunicates. The moderately developed predator/scavenger component is dominated by egg-brooding sea stars. Sensitivity to oil for the suspension-feeding component at the upper level probably is pretty similar to that predicted for Jakolof Bay, but the amount of impact would be less in the event of a spill on the west side of the inlet because of poorer development. Subtidally, the damage to the suspension-feeding and predator/scavenger components probably would be very great. Because of high turbidity year-round, a large proportion of the oil entering the area following a spill would enter the water column and come into contact with the epifauna. Furthermore, the trajectory models indicate that this oil would not have aged appreciably and would thus still contain a substantial proportion of the lighter, more toxic, fractions. These assemblages lack the protection of a kelp understory and probably the silt layer on the surface of the rocks and epifaunal crusts would become contaminated with oil and oily particles, increasing the amount of contact between the epifauna and oil. The effect of these oiled particles on these types of suspension feeders is unknown, but, considering their feeding mechanisms, they probably are quite sensitive and damage would be great. If a dispersant were used in clean-up efforts, this might increase the damage to the herbivore and predator-scavenger components because they are dominated by echinoderms.

Recovery following a major spill would probably require at least 25 years. The assemblages are dominated by high arctic species, growth rates are probably low and many of the species are brooders, implying that recolonization would require immigration by a benthic (rather than a planktonic) stage. Recruitment for species with planktonic larvae (e.g., Modiolus or the sea urchin) appears to range from fairly reliable to infrequent and thus many of these species would recover only slowly.

3. Specific Activities or Developments

Exploration and development of an oil field involve several different types of activities, installations, and potential perturbations. The major potential impacts from these activities include: 1) acute oil spills, 2) effects from drill cuttings and muds, 3) effects of cooling systems,

4) chronic contamination from formation waters, refinery wastes or ballast-treatment water, and 5) interference with fishing activities. The combination of potential impacts associated with each activity varies to a degree from those of other activities. Therefore, activity-specific impacts for most major activities are discussed below.

a. Drilling Platforms

The projected locations of exploratory drilling rigs in lower Cook Inlet (Warren 1978) are indicated in Figure 16. All are located in Federal water a moderate distance from all habitats and assemblages discussed in this report. In view of the turbulent nature of lower Cook Inlet, the most pertinent potential impact of drilling platforms would be from an acute oil spill. Potential effects of an acute oil spill have been discussed generally for Kennedy Entrance, Kachemak and Kamishak Bays in Section VII.D.2 above, but a few additional remarks are applicable. The assemblages in Kennedy Entrance and on the southern side of Kachemak Bay probably are quite similar; key species are kelps, but suspension feeders may be considerably more important in Kennedy Entrance. The assemblage on the northern shelf of Kachemak Bay is intermediate between these and the assemblage described for the west side of lower Cook Inlet; key species are kelps and suspension feeders, particularly the horse mussel *Modiolus* and the sea cucumbers *Cucumaria miniata* and *C. fallax*. This area has been designated a King Crab Sanctuary by the Alaska Department of Fish and Game because of its apparent importance to larval (Haynes 1977) and juvenile king crab (Sundberg and Clausen 1977). Key periods of the year extend from March through September in these rocky habitats. Kelp growth rates are highest from March through early June (Lees et al. 1979a). King crab enter the shallow habitats in February to molt and breed; they remain for several months. Salmon fry move into the marine environment in late April and early May; schools of fry are frequently observed in kelp beds. Larval and juvenile king crab are common in Kachemak Bay in July and August, particularly along the northern shelf between Bluff and Anchor Point (Sundberg and Clausen 1977). Larval and juvenile stages of many of the important epifaunal and infaunal species occur at peak densities from April

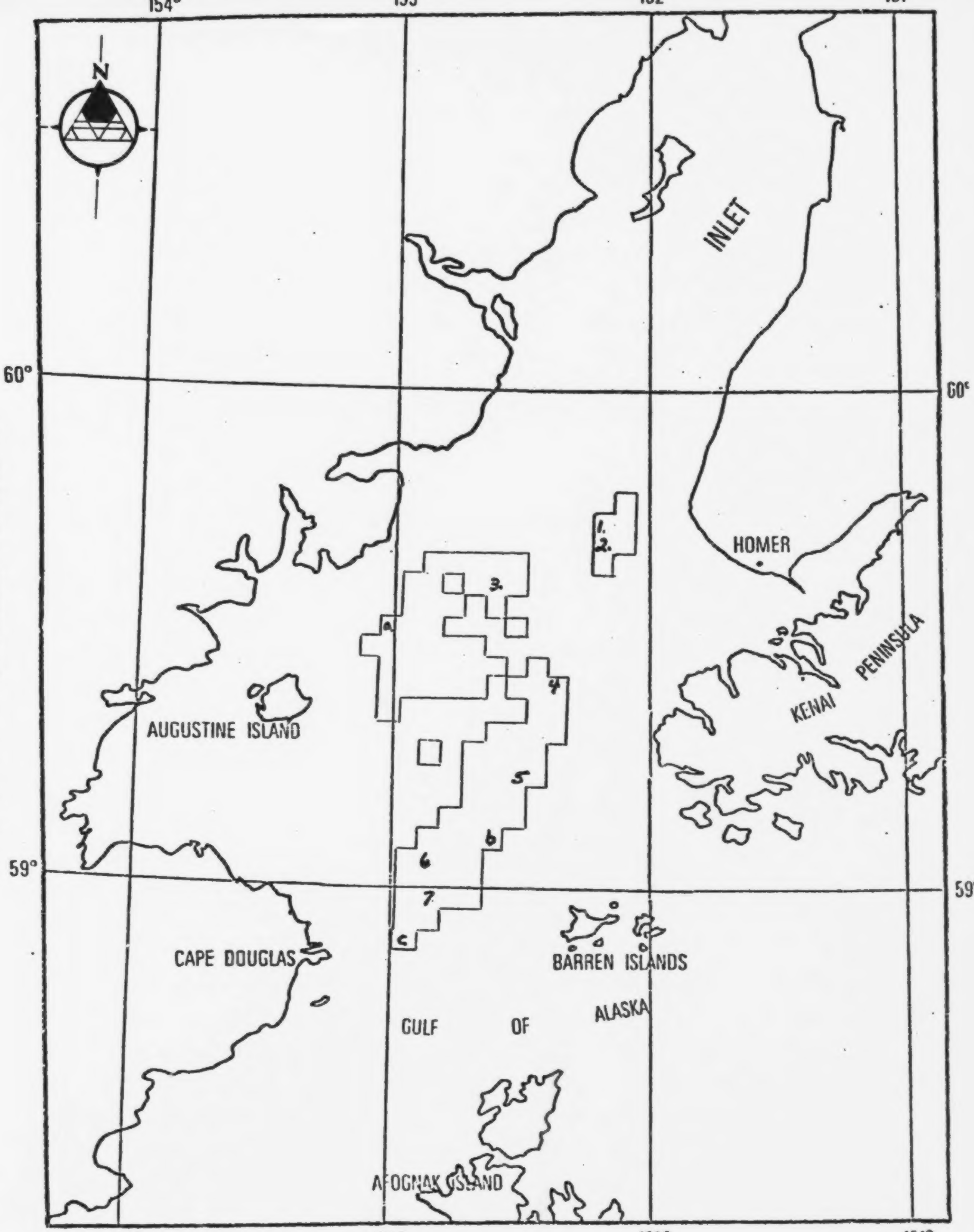
154°
153°
152°
151°
N
INLET
60°
60°
1.
2.
HOMER
3.
a
KENAI
PENINSULA
4
AUGUSTINE ISLAND
5
b
6
59°
59°
7
c
CAPE DOUGLAS
BARREN ISLANDS
GULF
OF
ALASKA
AFOGNAK ISLAND
154°
153°
152°
151°

FIGURE 16

PROJECTED LOCATIONS OF EXPLORATORY DRILLING RIGS AND POTENTIAL SPILL LOCATIONS IN LOWER COOK INLET THROUGH 1979

(from Warren. 1978)

through August. Several of the demersal fish species, especially greenling, "brood" their eggs in the shallow subtidal rock habitats until at least late September. Large numbers of dungeness crab (Cancer magister) often forage in Kachemak Bay in August and September and migrate out of Kachemak Bay across the northern shelf of Kachemak Bay in September and October.

Several organisms perceived by regulatory or decision-making agencies as "key" species occur periodically in the shallow subtidal rocky habitats; most are somewhat migratory, i.e., they are motile and do not reside in these habitats. Residence time of these migrants varies considerably. However, a major reason they come to a particular area is to feed. The large number and high abundance of the migratory species entering Kachemak Bay in the spring and summer is an indication of its importance and the large amount of food material available and concentrated here. Many of the food species utilized by these migratory species must therefore be recognized as "key" species, but the system is so diverse that it is still impractical to approach this task definitively. Community dominants have been suggested in Section VII.D.2, and further discussion would be repetitious.

b. Shore-based Facilities and Tanker Terminals

Potential new locations of shore-based facilities and tanker terminals (Warren 1978) are indicated in Figure 17. They include a possible support and supply facility at Homer, crude oil terminals and LNG plants in Kennedy Entrance and at Anchor Point, and production treatment facilities in Kennedy Entrance, at Anchor Point, and at Polly Creek, near Tuxedni Bay. No facilities are projected south of Tuxedni Bay on the west side of Cook Inlet. Thus, impacts from these potential facilities on shallow subtidal rocky habitats would mainly occur in Kennedy Entrance, in Kachemak Bay, and near Anchor Point.

The main impacts would arise from acute or chronic oil contamination. Acute spills could occur at all facilities and from tanker accidents. Chronic contamination could occur at the production treatment facilities (disposal of production water) and at tanker terminals (disposal of ballast water and numerous minor spills).

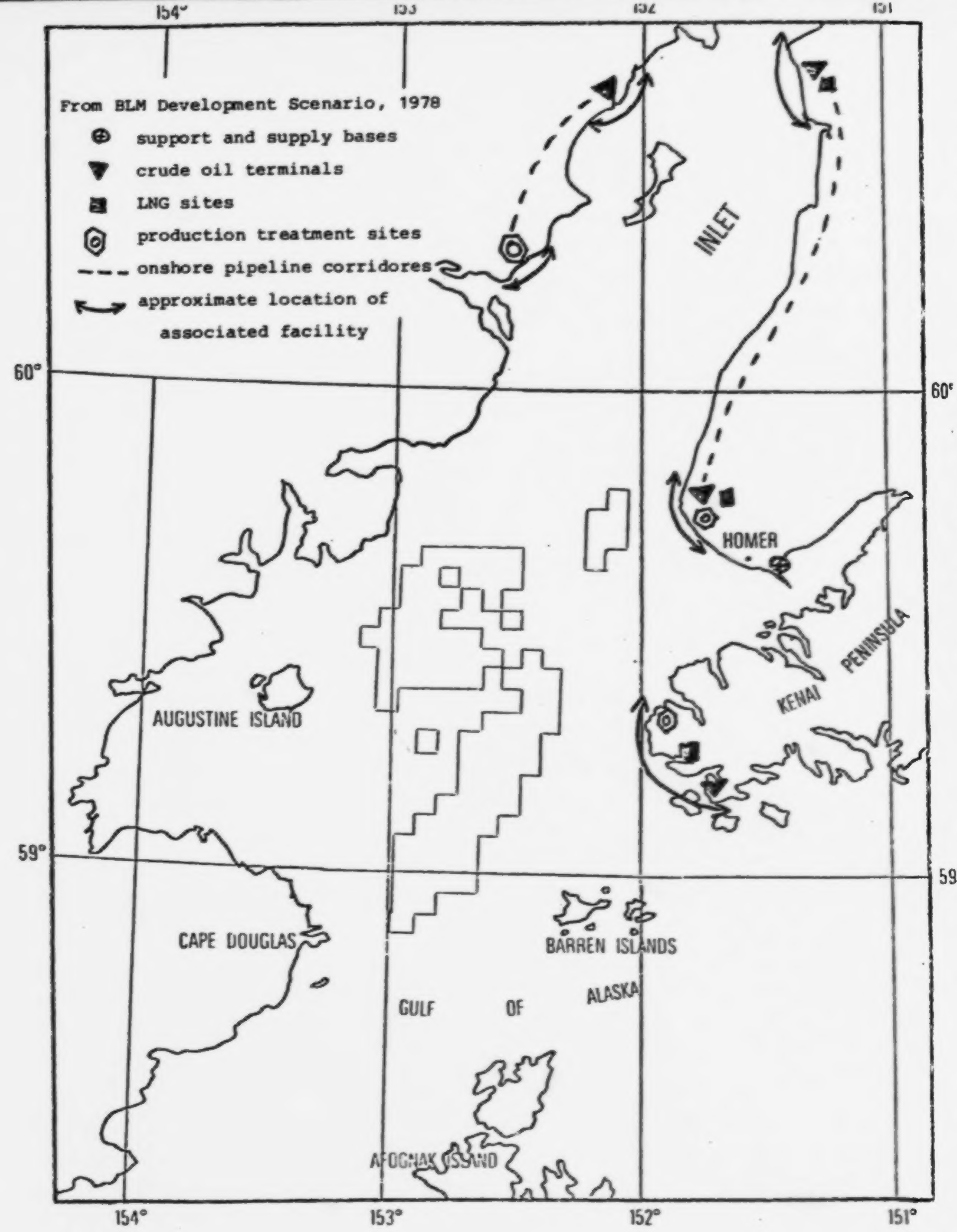
From BLM Development Scenario, 1978
⊕ support and supply bases
▼ crude oil terminals
■ LNG sites
⬡ production treatment sites
- - - onshore pipeline corridores
↔ approximate location of associated facility
INLET
HOMER
KENAI PENINSULA
AUGUSTINE ISLAND
CAPE DOUGLAS
BARREN ISLANDS
GULF OF ALASKA
AFOGNAK ISLAND
154°
153°
152°
151°
60°
59°

FIGURE 17

POTENTIAL LOCATIONS FOR ONSHORE FACILITIES ASSOCIATED WITH OIL EXPLORATION, DEVELOPMENT AND PRODUCTION IN LOWER COOK INLET

Although the assemblages in Kennedy Entrance are probably somewhat similar to these described for southern Kachemak Bay, descriptions of its shallow subtidal rocky habitats are not adequate to permit a detailed discussion (Lees 1977). Furthermore, these assemblages would probably be rather distant from the facilities. It seems probable that routine winter weather conditions would preclude safe, efficient tanker loading operations in the open waters of Kennedy Entrance, and thus would dictate that such facilities be located in its major embayments, i.e., Port Chatham, Koyuktolik Bay, or Port Graham. Thus, the main concern to shallow rocky subtidal assemblages would be acute oil spills, which were discussed in Section VII.D.2. The extreme turbulence of this area would probably act to greatly reduce the effects of either acute or chronic contamination by reducing duration of contact and dilution.

Consequences of either acute or chronic contamination in the vicinity of Anchor Point are of greater concern. Circulation studies indicate the presence of a gyre system in northwestern Kachemak Bay, over the northern shelf (Burbank 1977). Residence time of the water mass in this system is not clear, but large concentrations of larvae (Haynes 1977) suggest that it also could act to concentrate contaminants. As pointed out above, this area, supporting the northern shelf assemblage, has been designated as a King Crab Sanctuary and is part of the Kachemak Bay Critical Habitat area. Potential effects of oil contamination have been discussed in Section VII.D.2.

c. Pipelines

Pipelines are a potential concern because of the activities associated with laying the pipe and the possibility of breaks or small chronic leaks. Possible pipeline corridors are indicated in Figure 18 (Warren 1978). The only areas in which pipelines might affect shallow subtidal rocky habitats are in Kennedy Entrance and at Anchor Point. Pipelines would have to cross wide bands of rocky substrate in both locations (about 5 km and 10 km, respectively).

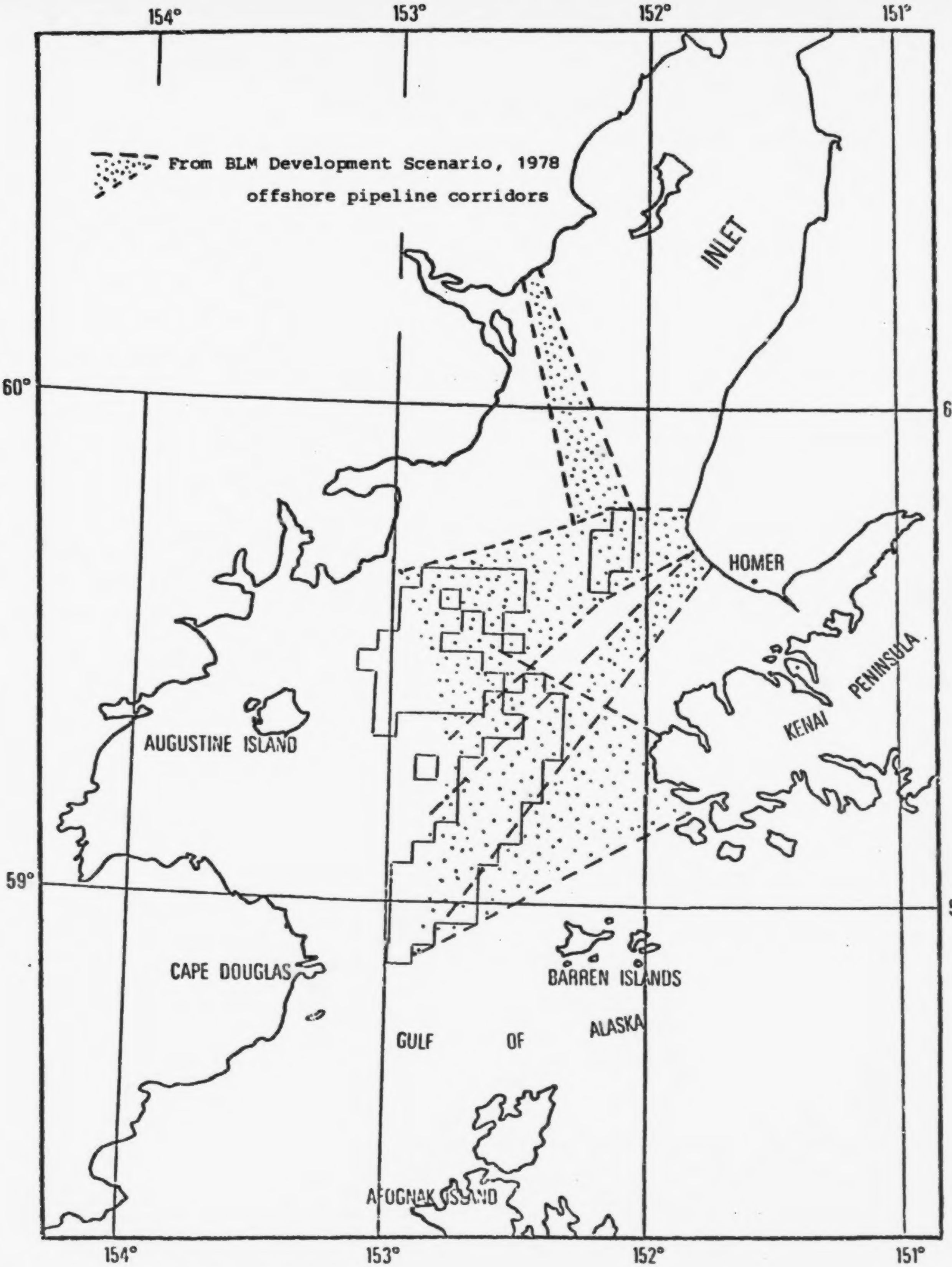
154°
153°
152°
151°
From BLM Development Scenario, 1978 offshore pipeline corridors
INLET
60°
60°
HOMER
KENAI PENINSULA
AUGUSTINE ISLAND
59°
59°
CAPE DOUGLAS
BARREN ISLANDS
GULF OF ALASKA
AFOGNAK ISLAND
154°
153°
152°
151°

FIGURE 18

POTENTIAL OFFSHORE PIPELINE CORRIDORS IN LOWER COOK INLET

(from Warren, 1978)

Activities associated with laying pipelines (blasting and dredging) would be restricted to pipeline routes and thus would affect rather limited areas.

A break in the pipeline would probably create an acute oil spill. The severity of the spill would depend upon the proximity of the break to the habitat and the amount of time required to stop the flow from the break. If the break occurred in the rocky habitat, it probably would be more damaging than a surface spill because the oil would be actively mixed with water and sediment particles as it rose to the surface. This is a special concern at Anchor Point because of the turbidity and the proximity to the King Crab Sanctuary.

Because of the high degree of turbulence in both locations, small chronic leaks in the pipeline would probably have no widespread effects unless the pollutants were concentrated by the gyre system.

d. Other Concerns

Tanker routes and physical disturbance from boats or aircraft associated with petroleum exploration and development are a concern to some other habitats or vertebrate assemblages, or may interrupt existing activities. However, tanker, boat and airplane activities constitute little threat to conditions in the shallow subtidal habitats discussed in this report, except as they involve access to the onshore facilities discussed above.

VIII. CONCLUSIONS

A. The three basic assemblages delimited in rocky, shallow subtidal habitats in lower Cook Inlet were generally geographically distinct.

1. The southern Kachemak Bay assemblage was generally characterized by a dense, well-developed, productive kelp component, a moderately well-developed sparse to abundant herbivore component, and poorly to well-developed suspension-feeding and predator/scavenger components. The kelp component included a well-developed surface canopy of *Alaria fistulosa* and/or *Nereocystis luetkeana*, and understory kelps extending deeper than 20 m. Factors influencing species composition and structure probably include strong tidal currents, and the oceanic characteristics of the water mass, i.e., the low concentrations of suspended solids and detritus, and high variability in suspended organic materials.

2. The northern Kachemak Bay assemblage was characterized by a moderately well-developed kelp component, a moderately well-developed and dense herbivore component, a moderate to massive development of the suspension-feeding component, and a well-developed predator/scavenger component. Surface canopies are patchy in time and space and understory kelps are common only to about 15 m. Species composition of the predator/scavenger component differs strongly on the northern and southern sides of Kachemak Bay. Factors that influence species composition and structure probably include the strong tidal currents, the moderate turbidity and dependable, abundant supply of suspended organic materials, and the density of herbivores.

3. The western Cook Inlet assemblage was characterized by poor development of the kelp component or its absence, a moderately diverse but sparse herbivore component, a complex, but thinly developed suspension-feeding component, and a poorly developed predator/scavenger component. The kelp component lacks a surface canopy and extends only slightly below 3 m. Factors influencing species composition and structure probably include ice scour, high turbidity, low salinity, seasonal alteration in periods of turbulence, sediment deposition and abrasion.

4. Rocky, shallow subtidal assemblages in Kachemak Bay (and probably Kennedy Entrance) (the southeastern quadrant of lower Cook Inlet) differ strongly from those observed in Kamishak Bay and at other locations examined on the western side of lower Cook Inlet. Fundamental differences are apparent in species composition, primary and secondary production, and probably exist in the level of complexity development, i.e., the level of succession attained.

5. Assemblages in the southeastern quadrant are closely allied to others in the northeastern Pacific Ocean whereas assemblages on the western side of lower Cook Inlet are more closely allied with assemblages described for the Bering and Beaufort Seas. No evidence is available to indicate a connection between the populations in lower Cook Inlet and the Bering Sea, so it appears that this assemblage may be a relict of an earlier geological period when sea level was appreciably higher.

6. The data base for Kennedy Entrance and the Barren Islands is insufficient.

B. The large horse mussel, Modiolus modiolus, an important, widespread suspension feeder on current-swept, cobble, gravel and bedrock, habitats bathes with turbid water. It is often found in association with high densities of several other suspension feeders.

1. Modiolus has been observed or reported in dense beds out to a depth of at least 40 m on the northern shelf of Kachemak Bay, along the eastern side of lower Cook Inlet between Anchor Point and Ninilchik, east of Chinitna Bay, and in low intertidal and shallow subtidal rocky habitats in northern Kamishak Bay out to a depth of about 5 m. A dense bed of Modiolus was observed in the entrance to Jakolof Bay but otherwise appeared uncommon on the southern side of Kachemak Bay.

2. Based on a comparison of size structures, the populations sampled were separated into two categories, i.e., bimodal Type 1 populations,

in which large adults dominated but juvenile or younger animals were common, and unimodal Type 2 populations, in which the population was limited to very large adults. Type 2 populations were only observed on the northern shelf of Kachemak Bay. In all populations, size structures indicated that recruitment rates were slow.

3. The starfish Evasterias troschelii, Orthasterias koehleri and Pycnopodia helianthoides appear to be the most important invertebrate predators on Modiolus. In the Jakolof Bay bed, these three species probably consume nearly 20 percent of the population. Although prey size is directly correlated with predator size, effort is biased toward Modiolus smaller than 65 mm shell length; approximately half the animals consumed are below 65 mm shell length whereas only about a third of the source population is below this size.

4. Based on the feeding observations at Jakolof Bay, the P:B ratio is somewhat less than 0.5, but production approaches 2 kg wet tissue/year.

C. Starfish, among the most important invertebrate predators in lower Cook Inlet, could be separated into three categories on the basis of food selection.

1. Henricia spp. appeared to specialize on sponges, although the validity of this observation is still somewhat questionable.

2. Pteraster and Dermasterias appeared to specialize on soft-bodied forms such as sponges, cnidarians, bryozoans, and tunicates, although Dermasterias is also known to feed on sea urchins.

3. Members of the genus Solaster fed on soft-bodied invertebrates but concentrated on other echinoderms, especially other starfish and sea cucumbers.

4. The last group, species with broad dietary selectivity, included Evasterias, Pycnopodia, Orthasterias, Leptasterias polaris and Crossaster. These species fed on a broad variety of mollusks and barnacles; many of the prey items were community dominants.

5. Groups 1, 2, and 3 comprised only starfish from the order Spinulosa whereas Group 4 comprised mainly forcipulate starfish.

D. The vulnerability of the shoreline to oil exposure in the event of a catastrophic oil spill is highest on the west side of lower Cook Inlet, especially from Chinitna Bay to Ursus Cove, intermediate on the northern shelf of Kachemak Bay, and low on the southern side of Kachemak Bay, and probably in Kennedy Entrance and on the Barren Islands; however, little information is available for Kennedy Entrance and the Barren Islands.

1. The most highly sensitive faunal assemblages probably are located on the northern shelf of Kachemak Bay and on the western side of lower Cook Inlet. The richest assemblages were observed on the northern shelf, and these assemblages would probably require the longest period of time to recover from damage. Except at Jakolof Bay, the southern side of Kachemak Bay was mainly dominated by kelp assemblages which have been generally recognized as fairly tolerant to the effects of acute oil spills. This situation is probably true in Kennedy Entrance and the Barren Islands.

2. Recovery of the shallow subtidal assemblages on rock habitats might require from five to ten years at most sites on the southern side of lower Cook Inlet to more than 20 years on the northern shelf of Kachemak Bay and on the western side of lower Cook Inlet. Because of the possibility that the latter assemblage is a relict, having a disjunct distribution from the Bering Sea and includes many species without planktonic larvae, recovery could require an extremely long time.

3. The main impact of concern from drilling platforms would be an acute oil spill, which could affect all of lower Cook Inlet as described

above. The main impacts of concern from shore-based facilities and tanker terminals are chronic and acute spills. In view of projected siting of such facilities, the main areas of concern are in Kennedy Entrance, in Kachemak Bay, and near Anchor Point. Because of the high degree of turbulence in these locations, chronic contamination may be of little importance. The most serious concern associated with underwater pipelines would be the possibility of a break, which could constitute an acute spill, but be more severe because of the release and subsequent mixture of large quantities of raw, unweathered crude oil into the water column in locations where mixing would be great. This could be extremely damaging to the benthic assemblages and planktonic larvae on the northern shelf of Kachemak Bay, where the higher turbidity of the water mass would increase the amount of oil retained in the water column.

IX. LITERATURE CITED

Baxter, R. E., 1971. Earthquake effects on clams of Prince William Sound. In: The Great Alaska Earthquake of 1964: Biology. NAS Pub. 1604, Washington, D.C., National Academy of Sciences.

Blackburn, J. E., 1977. Pelagic and demersal fish assessment in the lower Cook Inlet estuary system. Annual report from Alaksa Department of Fish and Game to NOAA, OCSEAP, 42 pp.

Boesch, D. F., C. F. Hershner, and J. H. Milgram, 1974. Oil spills and the marine environment. Ballinger Pub. Co., Cambridge, Mass.

Bouma, A. H., M. A. Hampton, M. L. Rappeport, P. G. Teleki, J. W. Whitney, R. C. Orlando, and M. E. Torresan, 1978. Movement of sandwaves in lower Cook Inlet, Alaska. Offshore Technology Conference, OTC 3311, 18 pp.

Burbank, D. C., 1977. Circulation studies in Kachemak Bay and Lower Cook Inlet, Vol. 3, pp. 207, In: Environmental Studies of Kachemak Bay and Lower Cook Inlet (L. L. Trasky, L. B. Flagg, and D. C. Burbank, eds.), Alaska Department of Fish and Game, Anchorage, Alaska.

Bureau of Land Management, 1976. Final Environmental Impact Statement, Proposed 1976 Outer Continental Shelf Oil and Gas Lease Sale, Lower Cook Inlet, Vol. 1, 562 pp.

Cunning, A., 1977. Baseline study of beach drift composition in Lower Cook Inlet, Alaska, 1976, Vol. XI, pp. 32. In: Environmental Studies of Kachemak Bay and Lower Cook Inlet (L. L. Trasky, L. B. Flagg, and D. C. Burbank, eds.), Alaska Department of Fish and Game, Anchorage, Alaska.

Dames & Moore, 1976. Oil spill trajectory analysis, Lower Cook Inlet, Alaska, for NOAA, OCSEAP.

__________, 1979. Final Draft. Oil spill trajectory analysis, Lower Cook Inlet, Alaska, for Bering Sea-Gulf of Alaska Project Office, OCSEAP, NOAA, 42 pp., Appendices A-D.

Driskell, W. B., and D. Lees, 1977. Benthic reconnaissance of Kachemak Bay, Alaska, Vol. VII, 102 pp. Environmental studies of Kachemak Bay and Lower Cook Inlet (L. L. Trasky, L. B. Flagg, and D. C. Burbank, eds.), Alaska Department of Fish and Game, Anchorage, Alaska.

Erikson, D., 1977. Distribution, abundance, migration and breeding locations of marine birds, Lower Cook Inlet, Alaska, 1976. Vol. VIII, 182 pp. Environmental studies of Kachemak Bay and Lower Cook Inlet (L. L. Trasky, L. B. Flagg, and D. C. Burbank, eds.), Alaska Department of Fish and Game, Anchorage, Alaska.

Green, J., 1968. The biology of estuarine animals. Univ. of Washington Press, Seattle. 401 pp.

Haynes, E. B., 1977. Summary status on the distribution of king crab and pandolid shrimp larvae, Kachemak Bay-Lower Cook Inlet, Alaska, 1976, Vol. IV, 52 pp. *In*: Environmental Studies of Kachemak Bay and Lower Cook Inlet (L. L. Trasky, L. B. Flagg, and D. C. Burbank, eds.), Alaska Department of Fish and Game, Anchorage, Alaska.

Kaczynski, V. W., R. J. Feller, J. Clayton, and R. G. Gerke, 1973. Tropic analysis of juvenile pink and churn salmon (*Oncorhyrchus gorbuscha* and *O. keta* in Puget Sound. J. Fish. Res. Bd. Canada 30:1003-1008.

Kolpack, R. L., 1971. Biological and oceanographical survey of the Santa Barbara Channel oil spill, 1969-1970. Vol. II. Physical, chemical and geological studies. Allan Hancock Foundation, Univ. of So. Calif., Los Angeles, 477 pp.

Larrance, J. D., and A. J. Chester, 1979. Source, composition and flux of organic detritus in lower Cook Inlet - Final report from Pac. Marine Environmental Lab, NOAA for NOAA, OCSEAP, 50 pp., Appendix A.

Lees, Dennis C., 1970. The relationship between movement and available food in the sea urchins *Strongylocentrotus franciscanus* and *Strongylocentrotus purpuratus*. Master's thesis. San Diego State Univ.

__________, 1976. The epifaunal assemblage in the Phillips Petroleum lease site off Spring Point, Chinitna Bay, Alaska. Dames & Moore final report for Phillips Petroleum Company, 42 pp.

__________, 1977. An ecological assessment of the littoral zone along the outer coast of the Kenai Peninsula. Dames & Moore final report for Alaska Department of Fish and Game, 101 pp.

__________, MS. Interactions between benthic assemblages and substrate in Lower Cook Inlet, Alaska. *In*: U.S. Geol. Survey, Professional Paper, ed. A. Bouma.

Lees, D. C., W. D. Driskell, D. Erikson, and D. Boettcher, 1979. Intertidal and shallow subtidal habitats of Port Valdez. Final report prepared by Dames & Moore for Alaska Petrochemical Co. 43 pp., Appendices 1-8.

Lees, D. C., and J. P. Houghton, 1977. Reconnaissance of the intertidal and shallow subtidal biotic assemblages in Lower Cook Inlet. Dames & Moore final report for Department of Commerce, NOAA, OCSAEP, 315 pp.

Lees, D. C., J. P. Houghton, D. Erikson, W. Driskell, and D. Boettcher, 1979. Ecological studies of intertidal and shallow subtidal habitats in Lower Cook Inlet. Dames & Moore annual report for Department of Commerce, NOAA, OCSEAP. 261 pp.

MacGinitie, G. E., 1955. Distribution and ecology of the marine invertebrates of Point Barrow, Alaska. Smithsonian Misc. Collections, Vol 128(9).

Mann, K. H., and R. B. Clark, 1978. Long-term effects of oil spills on marine intertidal communities. J. Fish. Res. Bd. Canada 35:791-795.

Mauzey, K. P., C. Birkeland, and P. K. Dayton, 1968. Feeding behavior of asteroids and escape responses of their prey in the Puget Sound Region. Ecology 49:603-619.

National Academy of Sciences, 1975. Petroleum in the Marine Environment, Washington, D. C.

Nelson-Smith, A., 1972. Oil pollution and marine ecology. Elek Science, London, England.

North, W. J., M. Neushul, and K. A. Clendenning, 1964. Successive biological changes observed in a marine cove exposed to a large spillage of mineral oil. Proc. Symp. Poll. Mar. Microorg. Prod. Petrol, Monaco:335.

Rice, S. D., A. Moles, T. L. Taylor, and J. F. Karinen, 1979. Sensitivity of 39 Alaskan marine species to Cook Inlet crude oil and No. 2 fuel oil, pp. 549-554. Proc. 1979 oil spill conf. sponsored by API, EPA, USCG, Los Angeles, March 19-22, 1979.

Rosenthal, R. J. and J. R. Chess, 1972. A predator-prey relationship between the leather star, Dermasterias imbricata, and the purple sea urchin, Strongylocentrotus purpuratus. Fishery Bulletin 20:205-216.

Rosenthal, R. J., and D. C. Lees, 1976. Marine plant community studies, Kachemak Bay, Alaska. Final report by Dames & Moore for Alaska Department of Fish and Game, 288 pp.

__________, 1979. A preliminary assessment of composition and food webs for demersal fish assemblages in several shallow subtidal habitats in lower Cook Inlet, Alaska. Dames & Moore, for Alaska Department of Fish and Game. 58 pp., Appendices I and II.

Sanger, G. A., R. D. Jones and D. W. Wiswar, 1979. The winter feeding habits of selected species of marine birds in Kachemak Bay, Alaska. Annual report of U.S. Fish and Wildlife Service to NOAA, OCSEAP, 35 pp.

Sibert, J., T. J. Brown, M. C. Healey, B. A. Kask, and R. J. Naiman, 1977. Detritus-based food webs: Exploitation by juvenile churn salmon (Oncorhynchus keta). Science 196:649-650.

Smith, J. (ed.), 1968. Torrey Canyon - Pollution and marine life. Report by the Plymouth Laboratory of the Marine Biological Assoc. of the United Kingdom. London, Cambridge Univ. Press, London, 196 pp.

Straughan, D., 1972. Factors causing environmental changes after an oil spill. J. Petrol. Tech. (March):250-254.

Sundberg, K. A., and D. Clausen, 1977. Post-larval king crab (Paralithodes kamtschatica) distribution and abundance in Kachemak Bay, Lower Cook Inlet, Alaska, 1976, Vol. V, pp. 36. In: Environmental studies of Kachemak Bay and Lower Cook Inlet (L. L. Trasky, L. B. Flagg, and D. C. Burbank, eds.), Alaska Department of Fish and Game, Anchorage, Alaska.

Warren, T. C., 1968. Lower Cook Inlet OCS: Results of sale and scenario of development, 19 pp. In: Environmental assessment of the Alaskan Continental Shelf, proceedings of the Lower Cook Inlet synthesis meeting, January 1978. U.S. Department of Commerce, NOAA, Boulder, Colorado.

X. APPENDICES

APPENDIX A-1 COVER AND ABUNDANCE DATA FOR ARCHIMANDRITOF SHOALS; 28 JUNE 1978. $\frac{1}{4}$ M^2 SQUARE QUADRATS FROM 4.6 M BELOW MLLW

TAXA						$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta							
Agarum cribrosum	(%)	0	10%	10%	15%	8.8 ± 6.3%	
		0	1	0	1	0.5 ± 0.6	2.0
ALGAE - Rhodophyta							
Coralline alga, encrusting	(%)	40%	40%	30%	60%	42.5 ± 12.6%	
INVERTEBRATA							
Abietinaria spp.	(%)	5%	T	0	3%	2.1 ± 2.3%	
Leptasterias polaris acervata		0	1	0	0	0.3 ± 0.5	1.0
Modiolus modiolus		2	8	4	4	4.5 ± 2.5	18.0
Potamilla ?reniformis	(%)	55%	45%	70%	40%	52.5 ± 13.2%	
Saxidomus giganteus		8	2	4	9	5.8 ± 3.3	23.0
Schizoplax brandtii		1	0	0	2	0.8 ± 1.0	3.0
Strongylocentrotus drobachiensis		13	12	10	12	11.8 ± 1.3	47.0
Tonicella lineata		5	3	1	12	5.3 ± 4.8	21.0
Trichotropis cancellata		1	0	0	0	0.3 ± 0.5	1.0

EXTRALIMITAL SPECIES:

ALGAE

Constantinea simplex
Desmarestia aculeata
Hildenbrandia sp
Nereocystis luetkeana
Pterosiphonia ?baileyi
Schizymenia sp

INVERTEBRATA

Abietinaria gigantea
A. kincaidi
Acmaea mitra
Buccinum glaciale
Cryptochiton stelleri
Elassochirus gilli
E. tenuimanus
Hyas lyrata
Neptunea lyrata
Owenia collaris
Panomya ampla
Pododesmus macroschisma
Pugettia gracilis
Sertularella reticula

CHORDATA

Lepidopsetta bilineata

Substrate: *Modiolus* bed, cobble with scattered boulders.

APPENDIX A-2a ABUNDANCE DATA FOR ARCHIMANDRITOF SHOALS; 28 JUNE 1978. 1 x 5 M^2 CONTIGUOUS QUADRATS FROM 6.7 M BELOW MLLW

TAXA	Frequency						$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta								
Agarum cribrosum, adult	0	1	0	0	1	0	0.3 ± 0.5	0.1
A. cribrosum, juvenile	2	2	3	3	2	1	2.2 ± 0.8	0.4
Laminaria groenlandica, juvenile	2	1	3	5	7	1	3.2 ± 2.4	0.6
Nereocystis luetkeana, juvenile	1	3	1	5	2	0	2.0 ± 1.8	0.4
INVERTEBRATA								
Crossaster papposus	0	1	0	1	0	0	0.3 ± 0.5	0.1
Fusitriton oregonensis	0	4	1	7	0	0	0.2 ± 2.9	0.4
Leptasterias polaris acervata	0	0	0	1	0	0	0.2 ± 0.4	0.03
L. ?hylodes	0	0	0	1	0	0	0.2 ± 0.4	0.03
Neptunea lyrata	1	4	0	1	0	0	1.0 ± 1.5	0.2
Solaster stimpsoni	0	0	0	0	1	0	0.2 ± 0.4	0.03

EXTRALIMITAL SPECIES:

ALGAE

Coralline alga, encrusting
Desmarestia aculeata
Pterosiphonia baileyi
Rhodymenia pertusae

INVERTEBRATA

Abietinaria gigantea
Acmaea mitra
Archidoris sp
Buccinum glaciale
Cribrinopsis similis
Crucigera zygophora
Cryptochiton stelleri
Elassochirus gilli
E. tenuimanus
Golfingia margaritacea
?*Hymedesanisochela* sp
Lebbeus grandimanus
Modiolus modiolus
Mycale lingua
Natica clausa
Oenopota spp
Oregonia gracilis
Owenia collaris
Pododesmus macroschisma
Psolus chitonoides
Saxidomus giganteus
Thelepus ?cincinnatus
Tonicella insignis
T. lineata
Trichotropis cancellata
T. insignis

Substrate: *Modiolus* bed, cobble matrix with scattered boulders; seaweed sparse

BEST DOCUMENT AVAILABLE

APPENDIX A-2b ABUNDANCE DATA FOR SELECTED SPECIES FROM ARCHIMANDRITOF SHOALS; 28 JUNE 1978

TAXA	Frequency										$\bar{x}$ ± s	Density (no./m^2)
INVERTEBRATA												
Modiolus modiolus	18	8	13	26	14	20	16	21	5	17	15.8 ± 6.2	63.2
Quadrat Size (m): ½ x ½ Depth below MLLW (m): 9.1												
Strongylocentrotus drobachiensis			35	34	43	38	25	30			34.2 ± 6.2	13.7
Quadrat Size (m): 0.5 x 5 Depth below MLLW (m): 6.7												
CHORDATA												
Cottidae, unid.						1						0.03
Lepidopsetta bilineata						1						0.03
Quadrat Size (m): 1 x 30 Depth below MLLW (m): 6.7												

BEST DOCUMENT AVAILABLE

APPENDIX A-3a FISH ABUNDANCE DATA FOR ARCHIMANDRITOF SHOALS; 10 JULY 1978.
TWO 1 x 25 M^2 QUADRATS FROM 15.5 M BELOW MLLW

TAXA	Frequency		Density (no./m^2)
Fish	0	0	0

EXTRALIMITAL SPECIES:

ALGAE - Rhodophyta

Coralline alga, encrust.
Rhodymenia palmata

INVERTEBRATA

Abietinaria giganteus
Abietinaria spp - C[a]
Balanus rostratus alaskanus - juv. common
Boreotrophon ?*stuarti*
Buccinum glaciale - C
Calycella syringa
Campanularia verticillata
Cancer oregonensis - C
Chlamys ?*hastatus* - C
Crepidula nummaria - C
Cryptobranchia concentrica - A[b]
Dendrobeania murrayana - C
Dendronotus ?*dalli* - S
Elassochirus gilli - S
E. tenuimanus - C
Flustrella gigantea - C
Fusitriton oregonensis - C
Halecium muricatum
Halocynthia aurantia - S[c]
Henricia sanguinolenta
Hyas lyrata
Ischnochiton albus
I. ?*trifidus* - S
Lafoea fruticosa
Leptasterias polaris acervata
L. ?*hylodes*
Modiolus modiolus - A
Musculus discors - S
Mycale lingua - C
Myxicola infundibulum
Natica clausa
Neptunea lyrata - C
Ophiopholis aculeata - C
Oregonia gracilis - C
Pagurus ?*dalli* - A
P. trigonocheirus
Pandalidae, unid. - S
Pododesmus macroschisma - C
Pteraster tesselatus
Serripes laperousii
Solaster dawsoni
Suberites ficus
Terminoflustra membranaceo-truncata
Thuiaria articulata - C
T. carica
T. distans
Tonicella insignis
Trophonopsis lasius

CHORDATA

Cottidae, unid. - 3
Lepidopsetta bilineata - 2

Substrate: Silty cobble with scattered boulder and mounds of *Modiolus modiolus*

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[a] C = Common

[b] A = Abundant

[c] S = Sparse

APPENDIX A-3b ABUNDANCE DATA FOR *MODIOLUS MODIOLUS* FROM ARCHIMANDRITOF SHOALS; 10 JULY 1978. ¼ M^2 SQUARE QUADRATS FROM 15.5 M BELOW MLLW

TAXA	Frequency										$\bar{x} \pm s$	Density (no./m^2)
Modiolus modiolus	54	93	37	33	4	21	32	19	22	21	33.6 ± 24.7	134.4

EXTRALIMITAL SPECIES:

INVERTEBRATA

- *Abietinaria* spp - common
- *Balanus* spp - common
- *Crossaster papposus*
- *Dendronotus dalli*
- *Fusitriton oregonensis*
- *Halocynthia aurantia*
- *Mycale lingua* - common
- *Pteraster tesselatus*
- *Solaster* sp
- *Trichotropis cancellata*
- *Triopha carpenteri*

CHORDATA

- *Lepidopsetta bilineata*
- ?*Myoxocephalus* sp

BEST DOCUMENT AVAILABLE

APPENDIX B-1 ABUNDANCE DATA FOR BLUFF POINT SUBTIDAL AREA; 31 JULY 1978.
¼ M^2 SQUARE QUADRATS FROM 10.1 M BELOW MLLW

TAXA		Frequency							$\bar{X} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta										
Agarum cribrosum	(%)	0	2%	0	0	0	0	0	0.3 ± 0.8%	
		0	1	0	0	0	0	0	0.1 ± 0.4	0.6
ALGAE - Rhodophyta										
Coralline alga, encrusting	(%)	70%	40%	30%	70%	60%	75%	80%	60.7 ± 18.8%	
Hildenbrandia sp	(%)	10%	0	10%	20%	0	20%	0	8.6 ± 9.0%	
Rhodophyta, foliose	(%)	5%	5%	0	10%	0	0	0	2.9 ± 3.9%	
INVERTEBRATA										
Abietinaria sp	(%)	0	0	0	0	5%	0	15%	2.9 ± 5.7%	
Acmaea mitra		0	0	2	0	0	0	0	0.3 ± 0.8	1.1
Alcyonidium pedunculatum	(%)	0	0	2%	0	0	0	0	0.3 ± 0.8%	
Calliostoma ligatum		0	0	P	0	0	0	0	-	P
Campanularia sp	(%)	0	2%	0	0	2%	5%	0	1.3 ± 1.9%	
Cancer oregonensis		0	1	0	0	0	1	0	0.3 ± 0.5	1.1
Elassochirus gilli		0	1	0	0	0	0	0	0.1 ± 0.4	0.6
Flustrella gigantea	(%)	15%	5%	2%	30%	15%	15%	0	7.9 ± 6.8%	
Fusitriton oregonensis		0	1	0	1	0	0	0	0.3 ± 0.5	1.1
Henricia sanguinolenta		1	0	0	0	0	0	0	0.1 ± 0.4	0.6
Heteropora sp	(%)	0	0	2%	0	0	0	0	0.3 ± 0.8%	
Microporina borealis	(%)	0	10%	0	0	5%	2%	2%	2.7 ± 3.7%	
Modiolus modiolus		3	0	2	3	3	3	0	2.0 ± 1.4	8.0
Neptunea lyrata		0	0	0	0	0	1	0	0.1 ± 0.4	0.6
Ophiopholis aculeata		P	0	0	0	P	0	0	-	P
Sabellidae, unid.	(%)	10%	0	5%	0	0	2%	0	2.4 ± 3.8%	
Strongylocentrotus drobachiensis		1	3	0	0	0	4	5	1.9 ± 2.1	7.4
Tonicella lineata		3	2	2	3	0	4	0	2.0 ± 1.5	8.0
Trichotropis cancellata		0	0	0	0	0	P	0	-	P
CHORDATA										
Artedius sp		0	0	1	0	0	2	0	0.4 ± 0.8	1.7

EXTRALIMITAL SPECIES: Bathymaster sp Hexagrammos stelleri

APPENDIX B-2 ABUNDANCE DATA FOR CONSPICUOUS ANIMALS FROM BLUFF POINT SUBTIDAL AREA; 31 JULY 1978. 0.5 X 25 M^2 BAND TRANSECTS FROM 15.6 M BELOW MLLW

TAXA	Frequency		$\bar{x} \pm s$	Density (no./m^2)
Fusitriton oregonensis				
(not on egg masses)	10	18	14.0 ± 5.7	1.1
(on egg masses)	3	5	4.0 ± 1.4	0.3
Nucella lamellosa	8	5	6.5 ± 2.1	0.5
Strongylocentrotus drobachiensis	5	0	2.5 ± 3.5	0.2
Trophon orpheus	1	1	1.0 ± 0.0	0.1

EXTRALIMITAL SPECIES:

Archidoris odneri
Cribrinopsis similis in association with Lebbeus grandimanus
Crossaster papposus
Triopha carpenteri

BEST DOCUMENT AVAILABLE

APPENDIX C-1   ABUNDANCE DATA FOR TROUBLESOME CREEK SUBTIDAL AREA; 1 AUGUST 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM 8 M BELOW MLLW

TAXA	Frequency						$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta								
Laminaria groenlandica	7	0	0	0	0	0	1.2 ± 2.9	0.5
INVERTEBRATA								
Cryptochiton stelleri	0	2	0	1	0	0	0.5 ± 0.8	0.2
Cucumaria miniata	61	74	91	97	66	61	75.0 ± 15.6	30.0
Henricia sp	1	1	0	0	2	0	0.7 ± 0.8	0.3
Neptunea lyrata	1	0	0	0	0	0	0.2 ± 0.4	0.1
Nudibranch, Dorid, white	0	1	0	0	0	0	0.2 ± 0.4	0.1
Strongylocentrotus drobachiensis	46	45	63	59	92	73	63.0 ± 17.7	25.2

Extralimital Species:

Nudibranch, Dorid, yellow

APPENDIX C-2 ABUNDANCE DATA FOR TROUBLESOME CREEK SUBTIDAL AREA; 1 AUGUST 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM 8.0 M BELOW MLLW

TAXA	Frequency					$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta							
Agarum cribrosum	1	1	0	3	0	1.0 ± 1.2	0.4
Desmarestia aculeata	0	0	4	0	0	0.8 ± 1.8	0.3
D. ligulata	1	0	0	0	0	0.2 ± 0.4	0.1
INVERTEBRATA							
Anthozoa, unid., white	0	4	3	2	-	2.3 ± 1.7	0.9
Cadlina ?luteomarginata	0	0	1	0	0	0.1 ± 0.4	0.1
Crossaster papposus	0	0	1	0	0	0.1 ± 0.4	0.1
Cryptochiton stelleri	1	0	0	1	0	0.4 ± 0.5	0.2
Cucumaria fallax	0	0	1	0	2	0.6 ± 0.9	0.2
C. miniata	31	39	59	67	42	47.6 ± 14.9	19.0
Elassochirus gilli	1	2	0	0	0	0.6 ± 0.9	0.2
Fusitriton oregonensis	0	1	0	1	0	0.4 ± 0.5	0.2
Henricia leviuscula	0	0	0	1	0	0.2 ± 0.4	0.1
H. sanguinolenta	0	0	0	1	0	0.2 ± 0.4	0.1
Hermissenda crassicornis	0	0	0	1	0	0.2 ± 0.4	0.1
Neptunea lyrata	0	1	0	0	0	0.2 ± 0.4	0.1
Strongylocentrotus drobachiensis	31	64	45	43	-	45.8 ± 13.6	18.3
Tealia sp.	2	2	2	2	3	2.2 ± 0.4	0.9

APPENDIX C-3 ABUNDANCE DATA FOR TROUBLESOME CREEK SUBTIDAL AREA; 1 AUGUST 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM 8.0 M BELOW MLLW

TAXA	Frequency					$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta							
Agarum cribrosum	0	1	0	0	1	0.4 ± 0.5	0.2
Desmarestia aculeata	0	1	5	0	0	1.2 ± 2.2	0.5
D. ligulata	0	0	2	0	0	0.4 ± 0.9	0.2
Laminaria groenlandica	0	0	2	0	0	0.4 ± 0.9	0.2
INVERTEBRATA							
Anthozoa, unid., white	0	0	1	3	5	1.8 ± 2.2	0.7
Crossaster papposus	1	0	0	0	1	0.4 ± 0.5	0.2
Cryptochiton stelleri	0	1	0	1	1	0.6 ± 0.5	0.2
Cucumaria fallax	1	0	1	0	0	0.4 ± 0.5	0.2
C. miniata	24	17	14	20	6	16.2 ± 6.8	6.5
Elassochirus gilli	2	0	1	0	0	0.6 ± 0.9	0.2
Evasterias troschelii	0	0	0	0	1	0.2 ± 0.4	0.1
Fusitriton oregonensis	1	0	1	0	0	0.4 ± 0.5	0.2
Hermissenda crassicornis	1	0	1	0	1	0.6 ± 0.5	0.2
Leptasterias ?hylodes	0	1	0	0	0	0.2 ± 0.4	0.1
Neptunea lyrata	0	0	1	0	0	0.2 ± 0.4	0.1
Octopus dofleini	0	1	0	0	0	0.1 ± 0.4	0.1
Strongylocentrotus drobachiensis	43	29	22	32	43	33.8 ± 9.1	13.5
Tealia crassicornis	0	0	2	0	0	0.4 ± 0.9	0.2

APPENDIX C-4 ABUNDANCE DATA FOR TROUBLESOME CREEK SUBTIDAL AREA; 1 AUGUST 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM 8.0 M BELOW MLLW

TAXA	Frequency						$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta								
Agarum cribrosum	2	1	1	0	3	0	1.2 ± 1.2	0.5
INVERTEBRATA								
Cryptochiton stelleri	0	0	1	0	0	0	0.2 ± 0.4	0.1
Cucumaria fallax	0	0	0	0	2	1	0.5 ± 0.8	0.2
C. miniata	28	23	6	12	24	33	21.0 ± 10.1	8.4
Henricia sp	0	0	0	1	0	0	0.2 ± 0.4	0.1
Strongylocentrotus drobachiensis	41	39	36	47	50	42	42.5 ± 5.2	17.0
Extralimital Species:								
Tonicella insignis								

APPENDIX C-5 ABUNDANCE DATA FOR TROUBLESOME CREEK SUBTIDAL AREA; 1 AUGUST 1978. ¼ M^2 SQUARE QUADRATS FROM 8.0 M BELOW MLLW

TAXA		Frequency						x ± s	Density (no./m^2)
ALGAE - Phaeophyta									
Agarum cribrosum	(%)*	2% 2	0 0	5% 1	0 0	5% 3	0 0	2.0 ± 2.4% 1.0 ± 1.3	4.0
ALGAE - Rhodophyta									
Coralline alga, encrusting	(%)	50%	50%	80%	50%	40%	-	54.0 ± 15.2%	
INVERTEBRATA									
Acmaea mitra		1	4	4	2	3	2	2.7 ± 1.2	10.7
Acmaeidae, unid.		3	0	0	0	0	0	0.5 ± 1.2	2.0
Amphissa columbiana		1	0	0	0	0	0	0.2 ± 0.4	0.7
Anthozoa, unid., white		2	0	0	0	0	0	0.3 ± 0.8	1.3
Calliostoma ligata		0	0	0	2	0	0	0.3 ± 0.8	1.3
Cryptochiton stelleri		0	0	0	1	0	0	0.2 ± 0.4	0.7
Cucumaria miniata	(%)	- 3	35% 12	40% 15	60% 20	25% 13	10% 5	34.0 ± 18.5% 11.3 ± 6.3	45.3
Elassochirus gilli		0	0	0	1	1	0	0.3 ± 0.5	1.3
Flustrella gigantea	(%)	5%	15%	5%	2%	6%	5%	6.3 ± 4.5%	
Fusitriton oregonensis		1	0	1	0	0	0	0.3 ± 0.5	1.3
Heteropora sp	(%)	1%	1%	2%	1%	1%	1%	1.2 ± 0.4%	
Margarites pupillus		4	0	0	0	0	0	0.7 ± 1.6	2.7
Metridium senile, juv.		3	1	6	0	6	3	3.2 ± 2.5	12.7
Mopalia sp		0	0	0	2	0	0	0.3 ± 0.8	1.3
Mya truncata		0	1	0	0	0	0	0.2 ± 0.4	0.7
Neptunea lyrata		1	0	0	0	0	0	0.2 ± 0.4	0.7
Paguridae, unid.		3	3	2	0	0	8	2.7 ± 2.9	10.7
Placiphorella sp		0	0	0	1	0	0	0.2 ± 0.4	0.7
Pugettia gracilis		1	2	2	0	0	0	0.8 ± 1.0	3.3
Ritterella ?pulchra	(%)	3%	6%	5%	1%	1%	2%	3.0 ± 2.1%	
Saxidomus giganteus		8	6	3	9	6	12	7.3 ± 3.1	29.3
Sertulariidae, unid.	(%)	7%	4%	2%	15%	10%	9%	7.8 ± 4.6%	

APPENDIX C-5 (Continued)

TAXA	Frequency						$\bar{x} \pm s$	Density (no./m^2)
Strongylocentrotus drobachiensis	3	7	24	4	7	9	9.0 ± 7.7	36.0
Tealia crassicornis	0	1	1	0	0	0	0.3 ± 0.5	1.3
Tonicella insignis	1	0	0	2	0	0	0.5 ± 0.8	2.0
T. lineata	0	2	3	2	0	4	1.8 ± 1.6	7.3
Trichotropis cancellata	0	1	0	0	0	0	0.2 ± 0.4	0.7

Extralimital Species:

ALGAE

Codium ritteri
Desmarestia ligulata
Hildenbrandia sp

INVERTEBRATA

Alcyonidium pedunculatum
Archidoris sp
Balanus nubilus
Cadlina luteomarginata
Crossaster papposus
Cucumaria fallax
Dendronotus alba
Elassochirus tenuimanus
Entodesma saxicola
Esperiopsis sp
Evasterias troschelii
Fusitriton oregonensis
Halcampa sp
Halocynthia aurantium
Henricia leviuscula
H. sanguinolenta
Hermissenda crassicornis
Macoma sp
Microporina borealis
Mycale lingua - common
Neptunea pribilofftensis- egg cases
Ophiopholis sp - abundant
Oregonia gracilis
Orthasterias koehleri
Rhynchozoon bispinosum
Sertularella reticulata
Solaster dawsoni
S. stimpsoni
Tealia lofotensis
Terebratalia transversa
Tresus capax
Velutina laevigata

CHORDATA

Hexagrammos stelleri
Liparis sp, orange

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[*] Unless noted, numbers indicate number of individuals.

APPENDIX C-6 ABUNDANCE DATA FROM TROUBLESOME CREEK SUBTIDAL AREA; 1 AUGUST 1978. ¼ M^2 SQUARE QUADRATS FROM 8.0 M BELOW MLLW

TAXA	Frequency										$\bar{x} \pm s$	Density (no./m^2)
INVERTEBRATA												
Ascidacea, unid.	0	0	0	0	0	0	0	0	0	2	0.2 ± 0.6	0.8
Balanus sp	0	0	0	0	0	0	0	0	2	0	0.2 ± 0.6	0.8
Cribrinopsis fernaldi	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	0.4
Cucumaria miniata	4	2	6	1	0	1	8	0	0	0	2.2 ± 2.9	8.8
Distaplia sp	0	0	0	3	0	0	1	14	0	0	1.8 ± 4.4	7.2
Flustrella gigantea (no. of colonies):	0	0	0	2	0	1	1	0	1	0	0.5 ± 0.7	2.0
Halichondria panicea (%)	0	0	0	0	0	0	0	0	0	70%	7.0 ± 22.1%	
Metridium senile	0	0	0	0	0	0	0	0	10	0	1.0 ± 3.2	4.0
Neptunea lyrata	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	0.4
Strongylocentrotus drobachiensis	1	4	4	4	5	0	5	4	1	3	3.1 ± 1.8	12.4

EXTRALIMITAL SPECIES:

Acmaea mitra
Anisodoris nobilis
Archidoris odhneri
Beringius kennicotti
Buccinum plectrum
Cancer oregonensis
Cribrinopsis similis
Crossaster papposus
Cryptochiton stelleri
Cucumaria fallax
Dermasterias imbricata
Elassochirus gilli
Evasterias troschelli
Fusitriton oregonensis
Gersemia sp
Henricia leviuscula
Neptunea pribiloffensis & eggs
Orthasterias koehleri
Solaster stimpsoni
Styela montereyensis
Tealia crassicornis
Tealia sp
Triopha carpenteri

CHORDATA

Hemilepidotus jordani
Hexagrammos lagocephalus

Substrate: Rock and cobble

APPENDIX C-7 ABUNDANCE DATA FROM TROUBLESOME CREEK SUBTIDAL AREA; 1 AUGUST 1978. ¼ M^2 SQUARE QUADRATS FROM 8.0 M BELOW MLLW

TAXA		Frequency									$\bar{x}$ ± s	Density (no./m^2)
INVERTEBRATA												
Abietinaria sp		3	0	0	10	0	0	3	4	0	2.2 ± 3.3	8.9
Cucumaria miniata		0	1	1	0	0	4	7	3	0	1.8 ± 2.4	7.1
Flustrella gigantea		0	0	2	0	2	1	0	0	0	0.6 ± 0.9	2.2
Hydrozoa, unid.	(%)	0	0	0	0	0	0	10%	5%	10%	2.8 ± 4.4%	
		0	0	0	0	0	0	6	6	10	2.4 ± 3.8	9.8
Mycale ?lingua	(%)	20%	0	0	0	0	0	0	0	0	2.2 ± 6.7%	
Porifera, unid.	(%)	10%	0	0	0	0	0	0	0	0	1.1 ± 3.3%	
		1	0	0	0	0	0	0	0	0	0.1 ± 0.3	0.4
Ritterella pulchra	(%)	10%	0	0	-	-	-	20%	0	30%	10.0 ± 12.6%	
no. of colonies:		5	0	0	1	2	2	6	0	10	2.9 ± 3.4	11.6
Strongylocentrotus drobachiensis		10	2	6	6	6	0	8	4	14	6.2 ± 4.2	24.9
Tunicata, unid., compound	(%)	10%	0	0	0	0	0	0	0	0	1.1 ± 3.3%	
no. of colonies:		1	0	0	0	0	0	0	0	0	0.1 ± 0.3	0.4

EXTRALIMITAL SPECIES:

INVERTEBRATA

Archidoris odhneri
Artedius sp
Calliostoma ligatum
Ceramaster arcticus
Cryptobranchia sp
Cucumaria fallax
Dermasterias imbricata
Doto cf *columbiana*
Eupentacta sp
Evasterias troschelli
Gersemia sp
Halocynthia aurantium
Ischnochiton albida
Neptunea lyrata
Ophiopholis aculeata
Paralithodes camtschatica
?*Petricola* sp
Phyllolithodes papillosus
Tonicella insignis
Tubularia sp

Substrate: Cobble and rock

APPENDIX C-8 ABUNDANCE DATA FROM TROUBLESOME CREEK SUBTIDAL AREA; 1 AUGUST 1978. ¼ M^2 SQUARE QUADRATS FROM 8.0 M BELOW MLLW

TAXA		Frequency									x̄ ± s	Density (no./m^2)
ALGAE - Chlorophyta												
Codium ritteri	(%)	0	5%	0	2%	0	0	0	0	0	0.8 ± 1.7%	
ALGAE - Phaeophyta												
Agarum cribrosum	(%)	0	0	0	0	0	15%	0	0	0	1.7 ± 5.0%	
		0	0	0	0	0	2	0	0	0	0.2 ± 0.7	0.9
ALGAE - Rhodophyta												
Coralline alga, encrust.	(%)	70%	60%	85%	0	50%	80%	60%	65%	80%	61.1 ± 25.6%	
INVERTEBRATA												
Abietinaria sp	(%)	10%	0	0	0	0	0	0	0	0	1.1 ± 3.3%	
Acmaea mitra		0	0	0	0	0	0	0	2	2	0.4 ± 0.9	1.8
Balanus nubilus	(%)	2%	0	0	-	0	0	0	0	0	0.3 ± 0.7%	
		1	0	0	6	0	0	0	0	0	0.8 ± 2.0	3.1
Cancer oregonensis		1	0	0	4	0	1	0	0	2	0.9 ± 1.4	3.6
Cribrinopsis similis		0	0	3	0	0	3	0	0	0	0.7 ± 1.3	2.7
Cucumaria fallax		0	0	0	1	0	0	0	0	0	0.1 ± 0.3	0.4
C. miniata		9	4	19	0	0	0	17	12	0	6.8 ± 7.7	27.1
Cucumaria sp, white		0	0	0	2	0	0	0	0	0	0.2 ± 0.7	0.9
Elassochirus gilli		0	1	0	2	0	0	2	0	1	0.7 ± 0.9	2.7
Flustrella gigantea	(%)	0	5%	5%	10%	0	2%	10%	10%	10%	5.8 ± 4.4%	
Fusitriton oregonensis		0	0	0	1	0	0	0	0	4	0.6 ± 1.3	2.2
Henricia sp		1	1	0	0	0	0	0	0	0	0.2 ± 0.4	0.9
Heteropora sp	(%)	5%	0	2%	0	0	2%	1%	2%	1%	1.4 ± 1.6%	
Ophiopholis sp		P	P	P	0	0	0	0	0	0	-	P
Oregonia gracilis		0	0	3	0	0	0	2	0	3	0.9 ± 1.4	3.6
Orthasterias koehleri		0	0	0	0	0	1	0	0	0	0.1 ± 0.3	0.4
Paguridae, unid.		P	0	0	0	0	0	0	0	0	-	P
Ritterella pulchra	(%)	15%	0	5%	5%	20%	1%	5%	0	15%	7.3 ± 7.4%	
Sertularella reticulata	(%)	0	10%	0	0	5%	2%	5%	5%	5%	3.6 ± 3.4%	
Strongylocentrotus drobachiensis		8	11	0	7	3	9	7	6	0	5.7 ± 3.9	22.7
Tonicella sp.		0	2	0	0	0	0	0	0	0	0.2 ± 0.7	0.9
CHORDATA												
Artedius sp		1	0	0	1	0	0	1	0	0	0.3 ± 0.5	1.3

Substrate: Rock

APPENDIX D-1 ABUNDANCE DATA FOR *NEREOCYSTIS LUETKEANA* FROM BARABARA BLUFF; 13 JULY 1978. 0.5 X 5 M QUADRATS FROM 9.8 - 10.7 M BELOW MLLW

TAXA	Frequency						$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta								
Nereocystis luetkeana (adults)	1	0	3	7	23	2	6.0 ± 8.7	2.4

Substrate: Bedrock and boulders

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APPENDIX D-2 COVER AND ABUNDANCE DATA FOR BARABARA BLUFF; 13 JULY 1978. ½ X 1 M QUADRATS FROM 9.8 - 10.7 M BELOW MLLW

TAXA												x ± s	Biomass (g/m)	Density (no./m)
ALGAE - Phaeophyta														
Agarum cribrosum (a)*	(%)	0	0	35	5	40	15	0	50	80	T**	22.6 ± 27.7%		
		0	0	6	2	10	4	0	4	14	0	4.0 ± 4.8		8.0
	(g)	-	0	225.7	19.5	290.7	30.5	0	146.1	695.3	0	156.4 ± 229.5	312.8	
Desmarestia aculeata	(%)	10	15	0	1	2	1	10	2	-	10	5.6 ± 5.7%		
	(g)	-	63.7	0	0	7.7	0	11.7	7.6	0	35.5	14.0 ± 21.8	28.0	
Laminaria groenlandica (a)	(%)	0	0	0	0	0	0	0	2	0	0	0.2 ± 0.6%		
		0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3		0.2
	(g)	-	0	0	0	0	0	0	5.2	0	0	0.6 ± 1.7	1.2	
Nereocystis luetkeana		4	8	0	0	0	0	1	0	3	2	1.8 ± 2.6		3.6
	(g)	5281.1	20469.0	0	0	0	0	1.8	0	1431.6	8.4	2719.2 ± 6454.8	5438.4	
ALGAE - Rhodophyta														
?Pterosiphonia sp	(%)	10	0	20	60	50	80	35	50	-	30	37.2 ± 25.4%		
INVERTEBRATA														
Cryptochiton stelleri		0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3		0.2
Strongylocentrotus drobachiensis		10	2	8	3	11	14	11	4	4	4	7.1 ± 4.2		14.2

Substrate: Bedrock and boulders, good fish habitat; many crevices and high relief

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*(a) = adult

** T = Trace

APPENDIX D-3 ABUNDANCE DATA FOR PLANTS AND FISH FOR BARABARA BLUFF; 13 JULY 1978. 0.5 X 30 M^2 QUADRAT FROM 9.8 - 10.7 M BELOW MLLW

TAXA	Frequency	Density (no./m^2)
ALGAE - Phaeophyta		
Nereocystis luetkeana	26	1.7
CHORDATA - Pisces		
Bathymaster sp	C*	
Hexagrammos decagrammus	C	
H. lagocephalus	C	
Sebastes melanops (juv.)	C	

Substrate: bedrock and boulder

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[*] C = Common

APPENDIX D-4 ABUNDANCE DATA FOR PLANTS AND ANIMALS FOR BARABARA BLUFF SUBTIDAL AREA; 13 JULY 1978. 2 X 5 M^2 CONTIGUOUS QUADRATS FROM 10.1 M BELOW MLLW

TAXA	Frequency					$\bar{x} \pm s$	Density (no./m^2)
Transect 1							
ALGAE - Phaeophyta							
Nereocystis luetkeana (a)*	6	1	3	1	8	3.8 ± 3.1	0.4
(j)**	1	0	3	0	5	1.8 ± 2.2	0.2
INVERTEBRATA							
Pycnopodia helianthoides	0	0	0	0	1	0.2 ± 0.4	0.02
CHORDATA - Pisces							
Hexagrammos decagrammus	1	0	0	0	0	0.2 ± 0.4	0.02
Transect 2							
ALGAE - Phaeopyta							
Nereocystis luetkeana (a)	1	15	18	7	8	9.8 ± 6.8	1.0
(j)	1	2	3	3	4	2.6 ± 1.1	0.3
CHORDATA - Pisces							
Hexagrammos decagrammus	0	1	0	0	0	0.2 ± 0.4	0.02
H. lagocephalus	1	0	0	0	0	0.2 ± 0.4	0.02
Transect 3							
ALGAE - Phaeophyta							
Nereocystis luetkeana (a)	0	2	4	11	5	4.4 ± 4.2	0.4
(j)	0	0	1	3	8	2.4 ± 3.4	0.2
CHORDATA - Pisces							
Bathymaster caerulofasciatus	0	1	0	0	0	0.2 ± 0.4	0.02
Hexagrammos decagrammus	3	0	0	0	0	0.6 ± 1.3	0.06

Extralimital species: Anarrhichthys ocellatus - female

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*(a) = adult
**(j) = juvenile

APPENDIX D-5 RECONNAISSANCE SURVEY FROM BARABARA BLUFF; 13 JULY 1978. 9.8 - 10.7 M BELOW MLLW

TAXA

ALGAE - Chlorophyta

Codium ritteri

ALGAE - Phaeophyta

Agarum cribrosum
Desmarestia aculeata
Laminaria groenlandica
Nereocystis luetkeana
Thalassiophyllum clathrus

ALGAE - Rhodophyta

Constantinea rosa-marina
Coralline alga, encrust.
Pterosiphonia sp
Ptilota sp
Schizymenia sp

CNIDARIA - Hydrozoa

Polyorchis sp

CNIDARIA - Scyphozoa

Aurelia labiata
Cyanea capillata
Haliclystus stejnegri

CNIDARIA - Anthozoa

Cribrinopsis similis
Tealia lofotensis

NEMERTEA

Tubulanus sexlineatus

TAXA

ANNELIDA - Polychaeta

Thelepus cincinnatus

ARTHROPODA - Crustacea

Elassochirus gilli
Lebbeus grandimanus

MOLLUSCA - Gastropoda

Acmaea mitra
Hermissenda crassicornis
Trichotropis cancellata

MOLLUSCA - Pelecypoda

Protothaca staminea
Saxidomus giganteus

MOLLUSCA - Polyplacophora

Cryptochiton stelleri
Tonicella insignis
T. lineata

ECTOPROCTA

Flustrella gigantea
Heteropora sp
Terminoflustra membranacea-truncata

ECHIURA

Bonelliopsis sp

TAXA

BRACHIOPODA
Terebratalia transversa

ECHINODERMATA - Asteroza

Crossaster papposus
Henricia sanguinolenta
Orthasterias koehleri
Pycnopodia helianthoides

ECHINODERMATA - Echinoidea

Strongylocentrotus drobachiensis
S. franciscanus

ECHINODERMATA - Ophiuroidea

Ophiopholis aculeata

CHORDATA - Tunicata

Distaplia occidentalis
Halocynthia aurantium

CHORDATA - Pisces

Anarrhichtys ocellatus
Bathymaster caerulofasciatus
Hexagrammos decagrammus
H. lagocephalus
Sebastes melanops
Sebastes sp A
Sebastes sp B

APPENDIX E-1a ABUNDANCE DATA FOR LAMINARIA GROENLANDICA FROM SCOTT ISLAND SUBTIDAL AREA; 15 JUNE 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM 2 M BELOW MLLW

TAXA	Frequency			$\bar{x}$ ± s	Density (no./m)
Laminaria groenlandica					
adults	5	14	3	7.3 ± 5.9	2.9
juveniles	1	3	2	2.0 ± 1.0	0.8

APPENDIX E-1b ABUNDANCE DATA FOR SCOTT ISLAND SUBTIDAL AREA; 15 June 1978. 0.5 x 5 M^2 QUADRATS FROM 2 M BELOW MLLW

TAXA						$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta							
Desmarestia aculeata	0	2	1	0	0	0.6 ± 0.9	0.2
Laminaria groenlandica	0	0	1	34	15	10.0 ± 14.8	4.0
L. ?*saccharina*	0	0	2	0	3	1.0 ± 1.4	0.4
ALGAE - Rhodophyta							
Callophyllis sp	0	2	0	0	2	0.8 ± 1.1	0.3
Constantinea sp	1	0	0	0	0	0.2 ± 0.4	0.1
Opuntiella californica	0	3	1	0	0	0.8 ± 1.3	0.3
Rhodymenia palmata	10	6	2	1	0	3.8 ± 4.1	1.5

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APPENDIX E-1c COVER AND ABUNDANCE DATA FOR SCOTT ISLAND SUBTIDAL AREA; 15 JUNE 1978. ¼ M^2 SQUARE QUADRATS FROM 2 M BELOW MLLW

TAXA		Frequency										$\bar{x}$ ± s	Biomass (g/m^2)	Density (no./m^2)
ALGAE - Phaeophyta														
Agarum cribrosum	(%)*	0	0	0	0	0	0	15%	0	0	0	1.5 ± 4.7%		
		0	0	0	0	0	0	0	0	0	0			0.0
Laminaria saccharina	(%)	80%	100%	40%	30%	0	100%	80%	20%	60%	30%	54.0 ± 35.0%		
		0	2	0	0	0	0	1	1	12	0	1.6 ± 3.7		6.4
	(g)	0	315.6	0	0	0	0	566.4	72.1	1647.4	0	260.2 ± 523.1	1040.6	

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* Unless noted, numbers indicate number of individuals

APPENDIX E-2 ABUNDANCE DATA FOR SCOTT ISLAND SUBTIDAL AREA, SOUTHWEST END; 4 AUGUST 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM 6 M BELOW MLLW

TAXA													$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta														
Agarum cribrosum	0	0	1	0	0	0	0	2	1	0	0	2	0.5 ± 0.8	0.2
Laminaria groenlandica	4	9	3	5	1	0	3	2	1	1	2	1	2.7 ± 2.5	1.1
INVERTEBRATA														
Anthozoa, unid., red	0	2	0	0	0	0	0	0	0	0	0	0	0.2 ± 0.6	0.1
Fusitriton oregonensis	0	3	0	0	0	0	0	0	0	0	0	1	0.3 ± 0.9	0.1
Henricia sanguinolenta	0	2	0	0	0	0	0	0	0	0	0	0	0.2 ± 0.6	0.1
Leptasterias sp	0	0	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	0.03
Pagurus sp	0	0	0	2	0	0	0	0	0	0	0	0	0.2 ± 0.6	0.1
Strongylocentrotus drobachiensis	0	2	0	0	0	0	0	0	0	0	0	0	0.2 ± 0.6	0.1
CHORDATA														
Hexagrammos stelleri	0	0	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	0.03

Extralimital Species:

Crossaster papposus
Elassochirus gilli
Naticidae egg
Solaster stimpsoni
Telmessus cheiragonus

ALGAE

Laminaria
Agarum cribrosum

INVERTEBRATA

Balanus sp
Elassochirus gilli
Hydrozoa, unid.
Leptasterias sp
Mopalia sp
Neptunea pribiloffensis-eggs
Porifera, unid.
Strongylocentrotus drobachiensis

Substrate: Sand bottom with occassional boulders

APPENDIX E-3 RECONNAISSANCE SURVEY FROM SCOTT ISLAND SUBTIDAL AREA, NORTHEAST END OF CHANNEL; 4 AUGUST 1978

TAXA	Depth Below MLLW (m) 4	 6
ALGAE - Phaeophyta		
Alaria taeniata	X	
Laminaria groenlandica	X	X
CHORDATA - Pisces		
Cottidae, unid.		X
Hexagrammos sp, juvenile	X	

Substrate: Bedrock and boulders with 3 ft. relief at 4 m and flat gravel area with shell debris and little silt at 6 m

APPENDIX F-1 RECONNAISSANCE SURVEY FROM KNOLL HEAD LAGOON REEF; 11 JUNE 1978

TAXA	Depth (m)*			
	1.1	2.6	3.0	3.3
ALGAE - Phaeophyta				
Agarum cribrosum	X		X	X
Alaria taeniata	X			
Laminaria groenlandica	X			
ALGAE - Rhodophyta				
Constantinea sp	X			X
Corallina sp	X			
Coralline alga, encrust.	X	X	X	X
Hildenbrandia sp		X		X
Odonthalia lyalli	X			
Tokidadendron bullata	X			
PORIFERA				
Halichondria panicea		X	X	
?*Mycale* sp (gray)		X		
Porifera, unid.		X		
Suberites ficus		X		
CNIDARIA - Hydrozoa				
Abietinaria filicula		X		
A. turgida		X		
Abietinaria spp			X	
CNIDARIA - Anthozoa				
?*Cribrinopsis similis*	X			
Tealia crassicornis	X			
ANNELIDA - Polychaeta				
?*Potamilla* sp			X	
ARTHROPODA - Crustacea				
Balanus hesperius laevidomus			X	
B. rostratus alaskanus		X		
Elassochirus gilli		X		
Pagurus beringanus		X		
MOLLUSCA - Gastropoda				
Buccinum glaciale		X		
Fusitriton oregonensis		X		
Neptunea borealis		X	X	
N. lyrata		X	X	
Nucella lima		X		
MOLLUSCA - Gastropoda cont.				
Trichotropis cancellata		X		
T. insignis		X		
MOLLUSCA - Pelecypoda				
Cyclocardia ?*stearnsi*			X	
Macoma obliqua			X	
Modiolus modiolus			X	
Pododesmus macroschisma		X		
MOLLUSCA - Polyplacophora				
Cryptochiton stelleri		X	X	
Ischnochiton albus		X	X	
Mopalia ciliata		X		
M. mucosa		X		
Tonicella insignis		X	X	
T. lineata		X		
ECTOPROCTA				
Costazia ?*surcularis*			X	
Flustrella gigantea		X		
Hippothoa hyalina		X		
BRACHIOPODA				
Terebratalia transversa		X		
ECHINODERMATA - Asteroidea				
Henricia sanguinolenta		X		
Leptasterias ?*hylodes*	X			
L. polaris acervata		X	X	
Leptasterias sp		X		
ECHINODERMATA - Echinoidea				
Strongylocentrotus drobachiensis		X	X	
ECHINODERMATA - Ophiuroidea				
Ophiopholis aculeata		X		
CHORDATA				
Hexagrammos stelleri		X		
Lepidopsetta bilineata		X		

Substrate: Boulder field at 1.1 m extending into gravel at 3.0 m below MLLW

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* Below MLLW

APPENDIX F-2a RECONNAISSANCE SURVEY FROM KNOLL HEAD LAGOON SUBTIDAL AREA; 2 AUGUST 1978.

TAXA	Depth (m)* 2.7-3.6	5.7
ALGAE - Phaeophyta		
Agarum cribrosum	X	
Laminaria groenlandica	X	
ALGAE - Rhodophyta		
Coralline alga, encrust.	X	X
Hildenbrandia sp	X	
Opuntiella californica	X	
PORIFERA		
Esperiopsis sp	X	
Halichondria panicea		X
Mycale ?lingua	X	
Porifera, unid., yellow	X	
CNIDARIA - Hydrozoa		
Abietinaria filicula		X
A. gigantea	X	
A. variabilis	X	
Sertularia cupressoides		X
CNIDARIA - Anthozoa		
Cribrinopsis sp	X	
ANNELIDA - Polychaeta		
Gattyana sp		X
ARTHROPODA - Crustacea		
Balanus rostratus alaskensis	X	
Balanus sp, juvenile		X
Elassochirus tenuimanus		X
Pagurus beringanus	X	X
P. kennerlyi	X	
Pagurus spp		X
MOLLUSCA - Gastropoda		
Acmaea mitra		X
Beringius kennicotti		X
Boreotrophon sp		X
Epitonium groenlandicum	X	
Fusitriton oregonensis	X	
MOLLUSCA - Gastropoda cont.		
Margarites pupillus	X	
Natica clausa		X
Neptunea lyrata		X
N. pribiloffensis	X	
Searlesia dira		X
Trichotropis cancellata	X	
T. insignis	X	
Trophonopsis lasius	X	
MOLLUSCA - Pelecypoda		
Modiolus modiolus	X	
Pododesmus macroschisma	X	
MOLLUSCA - Polyplacophora		
?Ischnochiton trifidus	X	
Mopalia ciliata	X	X
Tonicella insignis	X	
ECTOPROCTA		
Alcyonidium pedunculatum		X
Costazia surcularis	X	
Dendrobeania murrayana		X
Heteropora sp	X	
Hippothoa hyalina	X	
BRACHIOPODA		
Terebratalia transversus	X	
ECHINODERMATA - Asteroidea		
?Asterias amurensis, juv.		X
Henricia sanguinolenta		X
Leptasterias polaris acervata	X	X
Leptasterias ?hylodes		X
Pteraster tesselatus	X	
ECHINODERMATA - Echinoidea		
Strongylocentrotus drobachiensis	X	X
ECHINODERMATA - Ophiuroidea		
Ophiopholis sp	X	

Substrate: Large boulder at 2.7 m and gravel bed with scattered boulders at 5.7 m

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* Below MLLW

APPENDIX F-2b COVER AND ABUNDANCE DATA FOR KNOLL HEAD LAGOON, INNER STATION; 2 AUGUST 1978. ¼ M^2 SQUARE QUADRATS FROM +0.3 - 0.6 M BELOW MLLW

TAXA		Frequency										$\bar{x}$ ± s	Biomass (g/m^2)	Density ($no./m^2$)
ALGAE - Phaeophyta														
Alaria praelonga	(%)	*80%	100%	30%	50%	90%	75%	30%	10%	80%	80%	62.5 ± 30.3%		
		0	4	4	9	2	2	13	1	0	8	4.3 ± 4.3		17.2
	(g)	0	509.5	287.9	2717.8	197.8	130.8	57.3	187.1	0	1.4	409.0 ± 826.7	1635.8	
Laminaria groenlandica	(%)	10%	100%	25%	50%	20%	2%	20%	90%	0	0	31.7 ± 36.6%		
		0	4	10	13	1	2	1	3	0	0	3.4 ± 4.5		13.6
	(g)	0	698.2	1125.1	1152.3	38.4	426.0	122.7	856.9	0	0	442.0 ± 478.4	1767.8	

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* Unless noted, numbers indicate number of individuals.

APPENDIX F-2c ABUNDANCE DATA FOR KNOLL HEAD LAGOON, INNER STATION; 2 AUGUST 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM +0.3 - 0.6 M BELOW MLLW

TAXA	Frequency										$\bar{x} \pm s$	Density (no./m^2)
INVERTEBRATA												
Beringius kennicotti	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	0.04
Fusitriton oregonensis	5	0	0	0	0	0	0	0	0	1	0.6 ± 1.6	0.2
Neptunea lyrata	1	0	0	0	0	0	0	0	0	1	0.2 ± 0.4	0.1
Strongylocentrotus drobachiensis	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	0.04
Tealia/Cribrinopsis sp.	0	0	0	1	1	3	0	0	0	0	0.5 ± 1.0	0.2
Telmessus cheiragonus	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	0.04

Substrate: bedrock and boulders

APPENDIX F-2d ABUNDANCE DATA FOR KNOLL HEAD LAGOON SUBTIDAL AREA; 5 AUGUST 1978. 0.5 x 5 M^2 QUADRATS FROM 1.8 M BELOW MLLW

TAXA																	$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta																		
Agarum cribrosum	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	0.05
Alaria praelonga	5	2	1	0	0	0	0	4	0	2	4	4	6	1	1	2	2.0 ± 2.0	0.8
Desmarestia aculeata	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	0.05
Laminaria groenlandica	10	9	17	23	8	8	12	6	6	16	21	7	5	18	14	5	11.6 ± 5.9	4.6
CHORDATA																		
Hexagrammos octogrammus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	0.05
H. stelleri	0	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	0.3 ± 0.5	0.1

APPENDIX F-2e COVER AND ABUNDANCE DATA FOR KNOLL HEAD LAGOON SUBTIDAL AREA; 2 AUGUST 1978. ¼ M^2 SQUARE QUADRATS FROM 1.8 M BELOW MLLW

TAXA						$\bar{x}$ ± s	Density (no./m^2)
ALGAE - Phaeophyta							
Alaria praelonga	(%)	20%	50%	35%	30%	33.8 ± 12.5%	
		0	1	0	0	0.3 ± 0.5	1.0
Laminaria groenlandica	(%)	40%	40%	25%	25%	32.5 ± 8.7%	
		2	3	2	1	2.0 ± 0.8	8.0
ALGAE - Rhodophyta							
Constantinea subulifera	(%)	5%	3%	5%	6%	4.8 ± 1.3%	
Coralline alga, articulated	(%)	0	1%	1%	P	0.7 ± 0.6%	
Coralline alga, encrusting	(%)	70%	50%	60%	70%	62.5 ± 9.6%	
Hildenbrandia sp	(%)	0	0	P	0	P	
Odonthalia lyalli	(%)	10%	5%	8%	30%	13.3 ± 11.4%	
Tokidadendron bullata	(%)	15%	5%	15%	5%	10.0 ± 5.8%	
INVERTEBRATA							
Acmaeidae, unid		0	2	2	0	1.0 ± 1.2	4.0
?Anthopleura artemisia		3	0	3	2	2.0 ± 1.4	8.0
Costazia ?surcularis	(%)	0	0	0	1%	0.3 ± 0.5%	
Fusitriton oregonensis		0	1	0	0	0.3 ± 0.5	1.0
Leptasterias ?hylodes		0	1	0	0	0.3 ± 0.5	1.0
Margarites pupillus		0	0	2	0	0.5 ± 1.0	2.0
Modiolus modiolus		84	30	83	64	65.3 ± 25.2	261.0
Mopalia sp		1	1	2	0	1.0 ± 0.8	4.0
Musculus vernicosus		P	0	P	0		P
Mya sp		0	1	0	0	0.3 ± 0.5	1.0
Ophiopholis aculeata		P	P	P	P		P
Pagurus hirsutiusculus		0	2	0	3	1.3 ± 1.5	5.0
Pododesmus macroschisma		0	0	0	1	0.3 ± 0.5	1.0
Tonicella lineata		5	8	10	0	5.8 ± 4.3	23.0
Trichotropis insignis		4	1	0	1	1.5 ± 1.7	6.0
Trophonopsis lasius		0	0	0	1	0.3 ± 0.5	1.0

EXTRALIMITAL SPECIES: Hexagrammos lagocephalus H. octogrammus

Substrate: Bedrock and boulders with some cobble, shell and gravel

APPENDIX F-2f COVER AND ABUNDANCE DATA FOR KNOLL HEAD LAGOON OUTER STATION; 2 AUGUST 1978. ¼ M^2 SQUARE QUADRATS FROM 3.6 - 4.8 M BELOW MLLW

TAXA		Frequency										$\bar{x} \pm s$	Biomass (g/m^2)	Density ($no./m^2$)
ALGAE - Phaeophyta														
Agarum cribrosum	(%)*	5%	0	0	0	0	0	0	0	0	0	0.5 ± 1.6%		
		3	0	0	0	0	0	0	0	0	0	0.3 ± 0.9		1.2
	(g)	39.7	0	0	0	0	0	0	0	0	0	4.0 ± 12.6	15.9	
ALGAE - Rhodophyta														
Odonthalia lyalli	(%)	15%	1%	0	0	T**	0	0	0	0	3%	2.0 ± 4.7%		

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* Unless noted, numbers indicate number of individuals.

** T = Trace (<1%)

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APPENDIX F-2g ABUNDANCE DATA FOR KNOLL HEAD LAGOON, OUTER STATION; 2 AUGUST 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM 3.6 TO 4.8 M BELOW MLLW

TAXA																										$\bar{x} \pm s$	Density (no./m^2)
ALGAE - Phaeophyta																											
Agarum cribrosum	0	0	0	0	0	0	3	0	0	0	0	1	0	0	7	15	2	0	26	7	6	0	0	0	22	3.6 ± 7.1	1.4
Laminaria groenlandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	1	0.3 ± 0.5	0.1
INVERTEBRATA																											
Bucinnum glaciale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.04 ± 0.2	0.02
Crossaster papposus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.04 ± 0.2	0.02
Fusitriton oregonensis	0	0	0	0	1	0	3	0	0	0	0	2	0	0	1	3	9	4	12	4	6	0	0	5	10	2.4 ± 3.5	1.0
Henricia spp	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0.1 ± 0.3	0.05
Hermissenda crassicornis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04 ± 0.2	0.02
Leptasterias sp	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	2	0	0	2	0	0	0	0	0	0.4 ± 0.6	0.1
Neptunea lyrata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04 ± 0.2	0.02
Pododesmus macroschisma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	2	1	1	0	0	0	0	0	2	0.5 ± 1.0	0.2
Strongylocentrotus drobachiensis	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	0.05
Tealia/Cribrinopsis sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.04 ± 0.2	0.02
CHORDATA																											
Hexagrammos stelleri	0	0	0	0	0	0	0	2	0	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0.2 ± 0.5	0.1

Substrate: Gravel, cobble and boulders

APPENDIX G-1 RECONNAISSANCE SURVEY FROM WHITE GULL ISLAND SUBTIDAL AREA, WEST SIDE; 12 JUNE 1978

TAXA	Depth (m)* 0.2	1.1	1.2	2.3	1.2-3.6	2.8-4.0
ALGAE - Chlorophyta						
Chlorophyta, unid., filamentous			X			
Monostroma sp		X	X		X	
ALGAE - Phaeophyta						
Agarum cribrosum			X	X	X	
Alaria taeniata		X	X		X	
Desmarestia aculeata		X	X	X	X	
Laminaria groenlandica					X	
L. saccharina		X			X	
Laminaria sp				X		
ALGAE - Rhodymenia						
Coralline alga, encrust.					X	
R. palmata					X	
PROTOZOA						
Diatom cover			X			
PORIFERA						
Sigmadocia sp					X	
Porifera, unid., encrust. orange					X	
CNIDARIA - Hydrozoa						
Abietinaria variabilis					X	
Abietinaria sp						X

TAXA	Depth (m) 0.2	1.1	1.2	2.3	1.2-3.6	2.8-4.0
CNIDARIA - Hydrozoa cont.						
Calycella syringa					X	
Campanularia urceolata					X	
Lafoea fruticosa					X	
Obelia ?longissima					X	
Obelia sp					X	X
Sertularia cupressoides					X	
Thuiaria cylindrica					X	
CNIDARIA - Anthozoa						
Tealia lofotensis						X
ANNELIDA - Polychaeta						
Schizobranchia ?insignis					X	X
Terebellidae, unid.						X
ARTHROPODA - Crustacea						
Balanus ?crenatus					X	
B. rostratus					X	
Balanus sp			X	X		
Elassochirus tenuimanus					X	X
Hyas lyrata			X		X	
Pagurus beringanus					X	
P. hirsutiusculus					X	
P. ochotensis						X
Pagurus spp						X
Telmessus cheiragonus		X			X	

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APPENDIX G-1 (Continued)

TAXA	Depth (m)					
	0.2	1.1	1.2	2.3	1.2-3.6	2.8-4.0
MOLLUSCA - Gastropoda						
Boreotrophon ?clathrus			X			
B. pacificus			X			
B. glaciale			X			
Fusitriton oregonensis				X		
Lacuna sp				X		
Littorina sitkana	X					
Margarites pupillus					X	
Natica clausa			X		X**	
Neptunea lyrata			X		X	X
Oenopota levidensis						X
O. turricula						X
Oenopota spp						X
MOLLUSCA - Pelecypoda						
Astarte sp			X			
Clinocardium sp						X
Macoma sp			X			
?*Modiolus modiolus*						X
Pododesmus macroschisma					X	
MOLLUSCA - Polyplacophora						
Mopalia lignosa				X		
Tonicella lineata				X		

TAXA	Depth (m)					
	0.2	1.1	1.2	2.3	1.2-3.6	2.8-4.0
ECTOPROCTA						
Caulibugula sp			X	X	X	
Cystisella bicornis					X	
Dendrobeania murrayana					X	X
Eucratia loricata					X	X
Hippothoa hyalina					X	
ECHINODERMATA - Asteroidea						
Crossaster papposus				X		
Leptasterias hexactis			X			
L. polaris acervata			X	X		X
L. ?*hylodes*			X		X	
ECHINODERMATA - Echinoidea						
Strongylocentrotus drobachiensis, juvenile					X	
CHORDATA - Pisces						
Cottidae, unid.					X	
Hexagrammos stelleri				X	X	X
Lepidopsetta bilineata						X

Substrate:
0.2 m = Sand and gravel
1.1 m = Sand, gravel and shell debris shelf
1.2 m = Boulder field
2.3 m = Rock wall
1.2 - 3.6 m = Sand and gravel flats, boulder outcrops
2.8 - 4.0 m = Muddy gravel flats

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* Below MLLW
** Egg cases

APPENDIX G-2a RECONNAISSANCE SURVEY FROM WHITE GULL ISLAND SUBTIDAL AREA; 3 and 5 AUGUST 1978

TAXA

ALGAE - Phaeophyta

Alaria taeniata
Desmarestia viridis
Laminaria sp, juvenile

ALGAE - Rhodophyta

Schizymenia pacifica

PORIFERA

Esperiopsis quatsinoensis
Mycale lingua
Porifera, unid.,
Suberites ficus

CNIDARIA - Hydrozoa

Abietinaria variabilis
Irene ?indicans
Lafoea dumosa
Sertularella tenella
Sertularia cupressoides

CNIDARIA - Anthozoa

Anthozoa, unid., white
Cribrinopsis fernaldi
Cribrinopsis sp
Esperiopsis sp
Metridium senile
Tealia crassicornis

ANNELIDA - Polychaeta

Sabellidae, unid.
Schizobranchia sp

ARTHROPODA - Crustacea

Balanus rostratus
Caprella ?gracilior
Caridea, unid.
Elassochirus gilli
E. tenuimanus
Lebbeus sp
Pagurus beringanus
P. kennerlyi

TAXA

MOLLUSCA - Gastropoda

Aeolidia sp
Beringius kennicotti
Dendronotus sp
Dirona aurantia
Fusitriton oregonensis
Margarites pupillus
Neptunea lyrata
Velutina ?prolonga

MOLLUSCA - Pelecypoda

Modiolus modiolus
Musculus vernicosus

MOLLUSCA - Polyplacophora

Mopalia ciliata
Tonicella lineata

MOLLUSCA - Cephalopoda

Octopus dofleini

ECTOPROCTA

Alcyonidium polyoum
Bidenkapia sp
Dendrobeania murrayana
Ectoprocta, unid.
Eucratea loricata
Hippothoa hyalina
Lichenopora sp
Lagenipora ?socialis
Porella sp

ECHINODERMATA - Asteroidea

Crossaster papposus
Henricia sanguinolenta
Leptasterias polaris acervata
Solaster stimpsoni

ECHINODERMATA - Holothuroidea

Cucumaria miniata
Eupentacta quinquesemita
Psolus chitinoides

TAXA

ECHINODERMATA - Ophiuroidea

Ophiopholis aculeata

CHORDATA - Tunicata

Alcyonidium polyoum
Cnemidocarpa sp
Dendrodoa pulchella
Halocynthia aurantium
Styela montereyensis
Tunicata; unid.

CHORDATA - Pisces

Hexagrammos stelleri
Hexagrammos sp
Myoxocephalus spp
Ronquilus sp

APPENDIX G-2b COVER AND ABUNDANCE DATA FOR WHITE GULL ISLAND SUBTIDAL AREA; 3 AUGUST 1978. ¼ M^2 SQUARE QUADRATS FROM 0.4 - 5.0 M BELOW MLLW

TAXA						$\bar{x}$ ± s		Density (no./m^2)
ALGAE - Rhodophyta								
Coralline alga, encrust.	(%)*	0	0	1	0	0.3	0.5%	
Hildenbrandia sp	(%)	0	0	2%	0	0.5	1.0%	
INVERTEBRATA								
Abietinaria sp	(%)	0	2%	5%	3%	2.5	2.1%	
Alcyonidium pedunculatum	(%)	0	0	T**	T	0.3	0.3%	
Balanus rostratus	(%)	-	15%	10%	25%	16.7	7.6%	
Boreotrophon sp		0	0	1	4	1.3	1.9	5.0
Costazia ?surcularis	(%)	10%	10%	4%	3%	6.8	3.8%	
Cribrinopsis similis	(%)	0	0	0	15%	3.8	7.5%	
		0	0	0	1	0.3	0.5	1.0
Ectoprocta, unid., encrusting, orange	(%)	-	2%	1%	0	1.0	1.0%	
Esperiopsis ?laxa	(%)	0	1%	10%	3%	3.5	4.5%	
Margarites pupillus		0	0	1	3	1.0	1.4	4.0
Metridium senile, juv.		0	0	0	1	0.3	0.5	1.0
Mycale ?lingua	(%)	4%	6%	3%	2%	3.8	1.7%	
Sertulariidae, unid.	(%)	0	0	0	2%	0.5	1.0	2.0
Tonicella insignis		0	0	1	0	0.3	0.5	1.0
Dendrodoa pulchella	(%)	10%	28%	70%	15%	30.8	27.2%	
Tunicata, unid., white	(%)	0	3%	0	0	0.8	1.5%	

EXTRALIMITAL SPECIES:

INVERTEBRATA

- *?Halocynthia aurantia*
- *Henricia sanguinolenta*
- *Leptasterias ?hylodes*
- *Sertularia cupressoides*
- *Styela montereyensis*
- *Tealia crassicornis*

CHORDATA - Pisces

- *Bathymaster* sp
- *Hexagrammos stelleri*

Substrate: Sheer rock face from 0.4m - 4.4m, boulder field slope from 4.4m out to gravel at 11.1m below MLLW

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* Unless noted, numbers indicate number of individuals

** T = Trace

APPENDIX H RECONNAISSANCE SURVEY FROM BLACK REEF; 12 JUNE 1978

TAXA	Depth (m)* above 1.8	2.5	4.7	4.0	9.3
ALGAE - Phaeophyta					
Agarum cribrosum			X		
Alaria taeniata	X				
Laminaria groenlandica	X				
Laminaria sp		X			
ALGAE - Rhodophyta					
Coralline alga, encrust.	X		X		
Rhodymenia palmata	X		X		
PORIFERA					
Esperiopsis sp		X		X	
Halichondria panicea			X		
?*Halichondria* sp			X		
Hymendectyon ?*lyoni*			X		
?*Hymendesmia* sp			X		
Mycale sp			X		
Myxilla incrustans			X		
Porifera, unid., yellow			X		
Porifera, unid., orange			X		
Suberites sp			X		
CNIDARIA - Hydrozoa					
Abietinaria ?*amphora*			X		
A. variabilis			X		
Calycella syringa			X		
Eudendrium ?*irregulare*			X		
Hybocodon sp		X			

TAXA	Depth (m) above 1.8	2.5	4.7	4.0	9.3
CNIDARIA - Hydrozoa cont.					
Hydrallmania distans			X		
Lafoea fruticosa			X		
Sertularella tenella			X		
CNIDARIA - Anthozoa					
Anthopleura artemisia		X		X	
Cribrinopsis fernaldi		X			
Metridium senile		X			
Tealia sp		X			
ANNELIDA - Polychaeta					
Owenia collaris			X		
Platynereis bicaniculata			X		
Terebellidae, unid.		X			
ARTHROPODA - Crustacea					
Balanus rostratus		X	X		
Balanus sp		X			
Cancer oregonensis			X		
Elassochirus gilli		X			
Oregonia gracilis			X		
Pagurus hirsutiusculus			X		
P. kennerlyi			X		
Paguridae, unid.					X
Pandalidae, unid.		X		X	
Phyllolithodes papillosus				X	
Placetron wosnesenskii				X	

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APPENDIX H (Continued)

TAXA	Depth (m) above 1.8	2.5	4.7	4.0	9.3
MOLLUSCA - Gastropoda					
Acanthodoris ?pillosa		X			
?Beringius kennicotti			X		
Boreotrophon ?clathrus		X			
Buccinum glaciale			X		
Calliostoma ligata				X	
Coryphella sp		X			
Diaulula sandiegensis		X			
Dirona aurantia		X			
Fusitriton oregonensis			X		X
Margarites pupillus				X	
Neptunea lyrata, egg cases		X			
Nudibranchia, unid.		X			
Trichotropis cancellata		X		X	
T. insignis				X	
Trophonopsis lasius			X		
Velutina laevigata				X	
V. rubra				X	
Volutopsius castaneus, shell only			X		
MOLLUSCA - Pelecypoda					
Hiatella arctica				X	
Modiolus modiolus			X		
Musculus discors			X		
Mya truncata			X		
Pododesmus macroschisma		X			

TAXA	Depth (m) above 1.8	2.5	4.7	4.0	9.3
MOLLUSCA - Polyplacophora					
Ischnochiton trifidus			X		
Mopalia spp		X	X		X
Tonicella insignis			X		
T. lineata			X		
ECTOPROCTA					
Alcyonidium polyoum			X		
Bidenkapia spitsbergensis			X	X	
Costazia surcularis			X		
Ectoprocta, unid., digitate			X		
Ectoprocta, unid., encrust.			X		
Heteropora sp			X		
Hippothoa hyalina			X		
Lagenipora ?socialis			X		
Microporella sp			X		
M. plana			X		
Phidolopora sp			X		
Porella compressa			X		
Porella sp			X		
Terminoflustra membranacea truncata			X	X	
ENTOPROCTA					
Barentsia ?ramosa			X		
BRACHIOPODA					
Diastothyrus sp			X		
Hemithyrsis psittacea		X	X		
Terebratalia transversus		X	X		

APPENDIX H (Continued

	Depth (m)				
TAXA	above 1.8	2.5	4.7	4.0	9.3
ECHINODERMATA - Asteroidea					
Crossaster papposus		X		X	
Henricia leviuscula			X	X	
H. sanguinolenta		X	X		
H. tumida				X	
Leptasterias polaris acervata		X		X	
ECHINODERMATA - Echinoidea					
Strongylocentrotus drobachiensis			X		
ECHINODERMATA - Holothuroidea					
Eupentacta sp				X	
Psolus sp		X		X	
ECHINOIDEA - Ophiuroidea					
Ophiopholis aculeata			X		X
CHORDATA - Tunicata					
?*Cnemidocarpa* sp			X		
Dendrodoa sp			X		
Halocynthia aurantia		X	X		
Styela montereyensis			X	X	
Tunicata, unid., colonial		X		X	
CHORDATA - Pisces					
Cottidae, unid.		X			
Hexagrammos stelleri		X			

Substrate: Above 1.8 m = Rock
2.5 m = Vertical Face
4.7 m = Boulder
4.0 m = Overhang
9.3 m = Sand, gravel and silt with ripple marks

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* Below MLLW

APPENDIX I RECONNAISSANCE SURVEY FROM TURTLE REEFS; 5 AUGUST 1978

TAXA	Station I*	S**
ALGAE - Chlorophyta		
Spongomorpha sp	X	
ALGAE - Phaeophyta		
Alaria taeniata	X	
Fucus distichus	X	
Laminaria	X	X
ALGAE - Rhodophyta		
Rhodymenia palmata	X	
PORIFERA		
Halichondria panicea	X	
CNIDARIA - Anthozoa		
Anthopleura artemisia	X	
Cribrinopsis sp	X	X
Tealia crassicornis	X	
ARTHROPODA - Crustacea		
Balanus sp	X	
MOLLUSCA - Gastropoda		
Acmaea spp	X	
Calliostoma		X
littorina	X	
MOLLUSCA - Polyplacophora		
Tonicella lineata	X	
BRACHIOPODA		
Brachiopoda, unid.		X
Terebratalia sp		X
ECHINODERMATA - Asteroidea		
Crossaster papposus		X
Henricia sanguinolenta		X
ECHINODERMATA - Ophiuroidea		
Ophiopholis aculeata		X
CHORDATA - Tunicata		
Styela sp		X
Tunicata, unid.		X

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* I = Intertidal
** S = Subtidal, less than 2 m below MLLW

APPENDIX J   SUMMARY OF PREY SPECIES AND THEIR MAJOR PREDATORS

```
TISSUE UNID N =  17        PREDATOR SPECIES =  2
 94.1  %    ELASSOCHIRUS GILLI
 5.9   %    CANCER MAGISTER

FORAMINIFERA UNID N =  8   PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

DIATOMS UNID      N =  5   PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

ORGANISMS UNID    N =  4   PREDATOR SPECIES =  1
 100   %    PYCNOPODIA HELIANTHOIDES

TEREBRATALIA TRANSVERSUS   N =  1   PREDATOR SPECIES =  1
 100   %    ORTHASTERIAS KOEHLERI

HEMITHYRIS PSITTACEA       N =  1   PREDATOR SPECIES =  1
 100   %    PTERASTER TESSELATUS

CORALLINE ALGA    N =  1   PREDATOR SPECIES =  1
 100   %    PTERASTER TESSELATUS

LAMINARIA GROENLANDICA     N =  2   PREDATOR SPECIES =  2
 50    %    STRONGYLOCENTROTUS DROBACHIENSIS
 50    %    STRONGYLOCENTROTUS PALLIDUS

ALARIA FISTULOSA  N =  4   PREDATOR SPECIES =  4
 25    %    AMPHIPODA UNID
 25    %    GAMMARIDAE UNID
 25    %    LACUNA SP
 25    %    STRONGYLOCENTROTUS DROBACHIENSIS

AGARUM CRIBROSUM  N =  6   PREDATOR SPECIES =  2
 83.3  %    STRONGYLOCENTROTUS DROBACHIENSIS
 16.7  %    STRONGYLOCENTROTUS PALLIDUS

ALARIA SP   N =  5         PREDATOR SPECIES =  1
 100   %    KATHARINA TUNICATA

FUCUS DISTICHUS   N =  1   PREDATOR SPECIES =  1
 100   %    SIPHONARIA THERSITES

PORPHYRA SP N =  1         PREDATOR SPECIES =  1
 100   %    LITTORINA SITKANA

RHODOPHYTA UNID   N =  1   PREDATOR SPECIES =  1
 100   %    STRONGYLOCENTROTUS SP

PLANT UNID  N =  3         PREDATOR SPECIES =  2
 66.7  %    ELASSOCHIRUS GILLI
 33.3  %    NEPHTYS SP
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APPENDIX J (Continued)

```
PORIFERA UNID     N =  15  PREDATOR SPECIES =  5
 46.7  %    DERMASTERIAS IMBRICATA
 26.7  %    PTERASTER TESSELATUS
 13.3  %    HENRICIA SANGUINOLENTA
 6.7   %    ELASSOCHIRUS GILLI
 6.7   %    HENRICIA LEVIUSCULA

MYCALE LINGUA     N =  8   PREDATOR SPECIES =  2
 87.5  %    HENRICIA SANGUINOLENTA
 12.5  %    DERMASTERIAS IMBRICATA

ESPERIOPSIS LAXA  N =  2   PREDATOR SPECIES =  1
 100   %    PTERASTER TESSELATUS

MYCALE HISPIDA    N =  3   PREDATOR SPECIES =  2
 66.7  %    PTERASTER TESSELATUS
 33.3  %    DERMASTERIAS IMBRICATA

ESPERIOPSIS SP    N =  4   PREDATOR SPECIES =  1
 100   %    PTERASTER TESSELATUS

HALICHONDRIA PANICEA       N =  1   PREDATOR SPECIES =  1
 100   %    ARCHIDORIS MONTEREYENSIS

CLIONA CELATA     N =  1   PREDATOR SPECIES =  1
 100   %    HENRICIA LEVIUSCULA

LEUCOSOLENIA SP   N =  1   PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

HYDROZOA UNID     N =  7   PREDATOR SPECIES =  3
 42.9  %    ELASSOCHIRUS GILLI
 42.9  %    DERMASTERIAS IMBRICATA
 14.3  %    CROSSASTER PAPPOSUS

ANTHOZOA UNID     N =  3   PREDATOR SPECIES =  2
 66.7  %    SOLASTER STIMPSONI
 33.3  %    PTERASTER TESSELATUS

METRIDIUM SENILE  N =  50  PREDATOR SPECIES =  1
 100   %    DERMASTERIAS IMBRICATA

TEALIA CRASSICORNIS        N =  7   PREDATOR SPECIES =  1
 100   %    DERMASTERIAS IMBRICATA

ANTHOPLEURA SP    N =  1   PREDATOR SPECIES =  1
 100   %    DERMASTERIAS IMBRICATA

ABIETINARIA VARIABILIS     N =  5   PREDATOR SPECIES =  1
 100   %    DENDRONOTUS DALLI

ABIETINARIA SP    N =  9   PREDATOR SPECIES =  6
 33.3  %    ELASSOCHIRUS GILLI
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APPENDIX J (Continued)

```
 22.2 %    PTERASTER TESSELATUS
 11.1 %    DENDRONOTUS DALLI
 11.1 %    NUDIBRANCH UNID
 11.1 %    CROSSASTER PAPPOSUS

HYBOCODON PROLIFER         N =  1   PREDATOR SPECIES =  1
 100   %    AEOLIDIDA UNID

POLYCHAETA UNID    N =  4   PREDATOR SPECIES =  3
 50    %    ELASSOCHIRUS GILLI
 25    %    NEPHTYS SP
 25    %    SEARLESIA DIRA

SABELLIDAE UNID    N =  5   PREDATOR SPECIES =  3
 40    %    ELASSOCHIRUS GILLI
 40    %    ELASSOCHIRUS TENUIMANUS
 20    %    NEMERTEA UNID

NEPHTYS SP  N =  1          PREDATOR SPECIES =  1
 100   %    PAGURIDAE UNID

PLATYNEREIS BICANICULATA   N =  1   PREDATOR SPECIES =  1
 100   %    PARANEMERTES SP

SPIRORBINAE UNID   N =  1   PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

CISTENIDES GRANULATA       N =  1   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS POLARIS ACERVATA

BONELLIOPSIS SP    N =  9   PREDATOR SPECIES =  3
 66.7  %    SOLASTER STIMPSONI
 22.2  %    PYCNOPODIA HELIANTHOIDES
 11.1  %    TELMESSUS CHEIRAGONUS

ECHIURUS ECHIURUS N =  2   PREDATOR SPECIES =  1
 100   %    NEPHTYS SP

CRUSTACEAN UNID    N =  7   PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

OSTRACODA UNID     N =  2   PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

COPEPODA UNID      N =  2   PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

CIRRIPEDIA UNID    N =  1   PREDATOR SPECIES =  1
 100   %    CANCER MAGISTER

ISOPODA UNID       N =  1   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

AMPHIPODA UNID     N =  1   PREDATOR SPECIES =  1
```

APPENDIX J (Continued)

```
 100   %    ELASSOCHIRUS GILLI

BALANUS SP  N =  98        PREDATOR SPECIES =  6
 54.1  %    LEPTASTERIAS HEXACTIS
 18.4  %    EVASTERIAS TROSCHELII
 17.3  %    NUCELLA LAMELLOSA
 7.1   %    LEPTASTERIAS POLARIS ACERVATA
 2     %    ORTHASTERIAS KOEHLERI

GAMMARIDAE UNID   N =  9   PREDATOR SPECIES =  4
 44.4  %    ELASSOCHIRUS GILLI
 33.3  %    LEPTASTERIAS HEXACTIS
 11.1  %    NEREIS SP
 11.1  %    CANCER MAGISTER

PAGURIDAE UNID     N =  1   PREDATOR SPECIES =  1
 100   %    PYCNOPODIA HELIANTHOIDES

CANCER OREGONENSIS          N =  1   PREDATOR SPECIES =  1
 100   %    OCTOPUS RUBESCENS

TELMESSUS CHEIRAGONUS       N =  2   PREDATOR SPECIES =  2
 50    %    CRIBRINOPSIS SIMILIS
 50    %    PYCNOPODIA HELIANTHOIDES

BALANUS NUBILUS    N =  3   PREDATOR SPECIES =  2
 66.7  %    ORTHASTERIAS KOEHLERI
 33.3  %    NUCELLA LAMELLOSA

PENTIDOTEA WOSNESENSKII     N =  10  PREDATOR SPECIES =  2
 90    %    LEPTASTERIAS HEXACTIS
 10    %    TEALIA CRASSICORNIS

BALANUS CARIOSUS   N =  30  PREDATOR SPECIES =  2
 73.3  %    EVASTERIAS TROSCHELII  22
 26.7  %    NUCELLA LAMELLOSA       8

PENTIDOTEA SP      N =  3   PREDATOR SPECIES =  2
 66.7  %    VOLUTHARPA SP
 33.3  %    LEPTASTERIAS HEXACTIS

ANISOGAMMARUS SP   N =  1   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

DECAPODA UNID      N =  3   PREDATOR SPECIES =  2
 66.7  %    ELASSOCHIRUS GILLI
 33.3  %    EVASTERIAS TROSCHELII

TANAID UNID N =  1          PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

BALANUS CRENATUS   N =  54  PREDATOR SPECIES =  2
 98.1  %    EVASTERIAS TROSCHELII
 1.9   %    ORTHASTERIAS KOEHLERI
```

```
BALANUS GLANDULA  N =  5   PREDATOR SPECIES =  4
 40    %    NUCELLA EMARGINATA
 20    %    TEALIA CRASSICORNIS
 20    %    LEPTASTERIAS POLARIS ACERVATA
 20    %    LEPTASTERIAS HEXACTIS

BALANUS ROSTRATUS N =  1   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS POLARIS ACERVATA

PANDALUS HYPSINOTUS         N =  1   PREDATOR SPECIES =  1
 100   %    EVASTERIAS TROSCHELII

GNORIMOSPHAEROMA OREGONENSIS        N =  3   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

TROPHONOPSIS LASIUS         N =  3   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

VOLUTHARPA AMPULLACEA       N =  5   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

VOLUTHARPA SP     N =  1   PREDATOR SPECIES =  1
 100   %    PYCNOPODIA HELIANTHOIDES

BUCCINUM SP N =  1          PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

FUSITRITON OREGONENSIS      N =  5   PREDATOR SPECIES =  4
 40    %    PYCNOPODIA HELIANTHOIDES
 20    %    PAGURIDAE UNID
 20    %    OCTOPUS SP
 20    %    STRONGYLOCENTROTUS DROBACHIENSIS

ACMAEIDAE UNID    N =  7   PREDATOR SPECIES =  2
 85.7  %    LEPTASTERIAS HEXACTIS
 14.3  %    ORTHASTERIAS KOEHLERI

NATICA CLAUSA     N =  1   PREDATOR SPECIES =  1
 100   %    PYCNOPODIA HELIANTHOIDES

NUDIBRANCH UNID   N =  1   PREDATOR SPECIES =  1
 100   %    PUGETTIA GRACILIS

ACMAEA SCUTUM     N =  1   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

LITTORINA SITKANA N =  31  PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

ROSTANGA PULCHRA  N =  1   PREDATOR SPECIES =  1
 100   %    CROSSASTER PAPPOSUS

MARGARITES HELICINUS        N =  1   PREDATOR SPECIES =  1
```

```
 100   %    ELASSOCHIRUS GILLI

MARGARITES PUPILLUS        N =  2   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

DIODORA ASPERA    N =  1   PREDATOR SPECIES =  1
 100   %    ORTHASTERIAS KOEHLERI

NEPTUNEA SP N =  1         PREDATOR SPECIES =  1
 100   %    PAGURIDAE UNID

NATICA SP   N =  7         PREDATOR SPECIES =  1
 100   %    EVASTERIAS TROSCHELII

NEPTUNEA LYRATA   N =  3   PREDATOR SPECIES =  3
 33.3  %    OCTOPUS SP
 33.3  %    CROSSASTER PAPPOSUS
 33.3  %    LEPTASTERIAS HEXACTIS

TROPHON MULTICOSTATUS      N =  1   PREDATOR SPECIES =  1
 100   %    SPINULOSA UNID

ACMAEA PELTA      N =  1   PREDATOR SPECIES =  1
 100   %    EVASTERIAS TROSCHELII

PELECYPODA UNID   N =  1   PREDATOR SPECIES =  1
 100   %    CANCER MAGISTER

MODIOLUS MODIOLUS N =  230 PREDATOR SPECIES =  8
 69.1  %    EVASTERIAS TROSCHELII
 16.5  %    PYCNOPODIA HELIANTHOIDES
 11.7  %    ORTHASTERIAS KOEHLERI
 .9    %    LEPTASTERIAS POLARIS ACERVATA
 .4    %    TROPHONOPSIS LASIUS

ENTODESMA SAXICOLA         N =  20  PREDATOR SPECIES =  3
 75    %    EVASTERIAS TROSCHELII
 20    %    PYCNOPODIA HELIANTHOIDES
 5     %    ORTHASTERIAS KOEHLERI

MUSCULUS DISCORS  N =  6   PREDATOR SPECIES    4
 50    %    ORTHASTERIAS KOEHLERI
 16.7  %    CROSSASTER PAPPOSUS
 16.7  %    EVASTERIAS TROSCHELII
 16.7  %    LEPTASTERIAS POLARIS ACERVATA

SAXIDOMUS GIGANTEA         N =  48  PREDATOR SPECIES =  4
 87.5  %    PYCNOPODIA HELIANTHOIDES
 8.3   %    EVASTERIAS TROSCHELII
 2.1   %    SCYRA ACUTIFRONS
 2.1   %    FUSITRITON OREGONENSIS

MYA TRUNCATA      N =  6   PREDATOR SPECIES =  3
 66.7  %    PYCNOPODIA HELIANTHOIDES
```

APPENDIX J (Continued)

```
 16.7  %    EVASTERIAS TROSCHELII
 16.7  %    LEPTASTERIAS POLARIS ACERVATA

PANOMYA AMPLA      N =  1    PREDATOR SPECIES =  1
 100   %    PYCNOPODIA HELIANTHOIDES

PODODESMUS MACROSCHISMA      N =  2    PREDATOR SPECIES =  1
 100   %    ORTHASTERIAS KOEHLERI

MACOMA SP    N =  12         PREDATOR SPECIES =  4
 66.7  %    EVASTERIAS TROSCHELII
 16.7  %    PYCNOPODIA HELIANTHOIDES
 8.3   %    TELMESSUS CHEIRAGONUS
 8.3   %    NATICA CLAUSA

MYA SP N =   9      PREDATOR SPECIES =  3
 55.6  %    PYCNOPODIA HELIANTHOIDES
 33.3  %    LEPTASTERIAS POLARIS ACERVATA
 11.1  %    EVASTERIAS TROSCHELII

HUMILARIA KENNERLYI          N =  6    PREDATOR SPECIES =  1
 100   %    ORTHASTERIAS KOEHLERI

MYTILUS EDULIS     N =  109 PREDATOR SPECIES =  7
 47.7  %    NUCELLA LAMELLOSA
 33.9  %    EVASTERIAS TROSCHELII
 14.7  %    LEPTASTERIAS HEXACTIS
 .9    %    METRIDIUM SENILE
 .9    %    HYAS LYRATUS

PROTOTHACA STAMINEA          N =  9    PREDATOR SPECIES =  3
 55.6  %    EVASTERIAS TROSCHELII
 33.3  %    PYCNOPODIA HELIANTHOIDES
 11.1  %    LEPTASTERIAS POLARIS ACERVATA

CLINOCARDIUM SP    N =  13   PREDATOR SPECIES =  1
 100   %    EVASTERIAS TROSCHELII

TRESUS CAPAX       N =  4    PREDATOR SPECIES =  2
 75    %    EVASTERIAS TROSCHELII
 25    %    CHIONOECETES BAIRDI

SERRIPES GROENLANDICUS       N =  1    PREDATOR SPECIES =  1
 100   %    EVASTERIAS TROSCHELII

CLINOCARDIUM CALIFORNIENSE N =  1    PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS POLARIS ACERVATA

MACOMA BALTHICA    N =  2    PREDATOR SPECIES =  2
 50    %    NATICA SP
 50    %    LEPTASTERIAS POLARIS ACERVATA

MACOMA OBLIQUA     N =  1    PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS POLARIS ACERVATA
```

APPENDIX J (Continued)

```
MYA ARENARIA      N =  1   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS POLARIS ACERVATA

POLYPLACOPHORA UNID        N =  2   PREDATOR SPECIES =  1
 100   %    CROSSASTER PAPPOSUS

CRYPTOCHITON STELLERI      N =  3   PREDATOR SPECIES =  2
 66.7  %    STRONGYLOCENTROTUS DROBACHIENSIS
 33.3  %    FUSITRITON OREGONENSIS

KATHARINA TUNICATA         N =  6   PREDATOR SPECIES =  3
 66.7  %    LEPTASTERIAS HEXACTIS
 16.7  %    METRIDIUM SENILE
 16.7  %    EVASTERIAS TROSCHELII

MOPALIA CILIATA   N =  1   PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS HEXACTIS

SCHIZOPLAX BRANDTII        N =  1   PREDATOR SPECIES =  1
 100   %    FLIES UNID

MOPALIA SP  N =  1         PREDATOR SPECIES =  1
 100   %    LEPTASTERIAS POLARIS ACERVATA

ECTOPROCTA UNID   N =  3   PREDATOR SPECIES =  2
 66.7  %    CROSSASTER PAPPOSUS
 33.3  %    ELASSOCHIRUS GILLI

FLUSTRELLA GIGANTEA        N =  2   PREDATOR SPECIES =  2
 50    %    CROSSASTER PAPPOSUS
 50    %    PTERASTER TESSELATUS

ECTOPROCTA ENCRUSTING      N =  1   PREDATOR SPECIES =  1
 100   %    STRONGYLOCENTROTUS DROBACHIENSIS

ALCYONIDIUM SP    N =  1   PREDATOR SPECIES =  1
 100   %    CROSSASTER PAPPOSUS

FLUSTRELLA SP     N =  6   PREDATOR SPECIES =  1
 100   %    ELASSOCHIRUS GILLI

MICROPORINA BOREALIS       N =  1   PREDATOR SPECIES =  1
 100   %    PTERASTER TESSELATUS

ALCYONIDIUM PEDUNCULATUM   N =  1   PREDATOR SPECIES =  1
 100   %    CROSSASTER PAPPOSUS

DERMASTERIAS IMBRICATA     N =  1   PREDATOR SPECIES =  1
 100   %    PYCNOPODIA HELIANTHOIDES

EVASTERIAS TROSCHELII      N =  2   PREDATOR SPECIES =  2
 50    %    SOLASTER DAWSONI
 50    %    SOLASTER STIMPSONI
```

APPENDIX J (Continued)

STRONGYLOCENTROTUS DROBACHIENSIS N = 50 PREDATOR SPECIES = 7

84	%	PYCNOPODIA HELIANTHOIDES
4	%	ELASSOCHIRUS GILLI
4	%	FUSITRITON OREGONENSIS
2	%	CRIBRINOPSIS SIMILIS
2	%	ACTINIARIA UNID

STRONGYLOCENTROTUS SP N = 6 PREDATOR SPECIES = 2

83.3	%	ELASSOCHIRUS GILLI
16.7	%	CROSSASTER PAPPOSUS

CUCUMARIA SP N = 18 PREDATOR SPECIES = 5

38.9	%	LEPTASTERIAS HEXACTIS
27.8	%	SOLASTER STIMPSONI
11.1	%	DERMASTERIAS IMBRICATA
11.1	%	PYCNOPODIA HELIANTHOIDES
11.1	%	SOLASTER DAWSONI

CUCUMARIA VEGAE N = 1 PREDATOR SPECIES = 1

100	%	SOLASTER STIMPSONI

OPHIUROIDEA UNID N = 6 PREDATOR SPECIES = 1

100	%	ELASSOCHIRUS GILLI

TUNICATA UNID N = 1 PREDATOR SPECIES = 1

100	%	SOLASTER STIMPSONI

HALOCYNTHIA AURANTIUM N = 1 PREDATOR SPECIES = 1

100	%	ORTHASTERIAS KOEHLERI

CNEMIDOCARPA FINMARKIENSIS N = 1 PREDATOR SPECIES = 1

100	%	FUSITRITON OREGONENSIS

MYOXOCEPHALUS POLYACANTHOCEPHALUS N = 4 PREDATOR SPECIES = 3

50	%	AMPHISSA SP
25	%	BUCCINUM SP
25	%	FUSITRITON OREGONENSIS

PHOLIS LAETA N = 1 PREDATOR SPECIES = 1

100	%	OCTOPUS SP

note: data does not include vertebrate predators

APPENDIX K   SUMMARY OF PREY GROUPS WITH MAJOR PREDATOR SPECIES

```
ALGAE          N =  24        PREDATOR SPECIES =  12
 29.2  %     STRONGYLOCENTROTUS DROBACHIENSIS
 20.8  %     KATHARINA TUNICATA
 8.3   %     ELASSOCHIRUS GILLI
 8.3   %     STRONGYLOCENTROTUS PALLIDUS
 4.2   %     NEPHTYS SP

FORAMINIFERA      N =  8   PREDATOR SPECIES =  1
 100   %     ELASSOCHIRUS GILLI

PORIFERA       N =  35        PREDATOR SPECIES =  6
 34.3  %     PTERASTER TESSELATUS
 25.7  %     DERMASTERIAS IMBRICATA
 25.7  %     HENRICIA SANGUINOLENTA
 5.7   %     ELASSOCHIRUS GILLI
 5.7   %     HENRICIA LEVIUSCULA

HYDROZOA       N =  22        PREDATOR SPECIES =  7
 27.3  %     ELASSOCHIRUS GILLI
 27.3  %     DENDRONOTUS DALLI
 18.2  %     DERMASTERIAS IMBRICATA
 9.1   %     CROSSASTER PAPPOSUS
 9.1   %     PTERASTER TESSELATUS

ANTHOZOA       N =  61        PREDATOR SPECIES =  3
 95.1  %     DERMASTERIAS IMBRICATA
 3.3   %     SOLASTER STIMPSONI
 1.6   %     PTERASTER TESSELATUS

POLYCHAETA     N =  13        PREDATOR SPECIES =  8
 38.5  %     ELASSOCHIRUS GILLI
 15.4  %     ELASSOCHIRUS TENUIMANUS
 7.7   %     NEMERTEA UNID
 7.7   %     PARANEMERTES SP
 7.7   %     NEPHTYS SP

ECHIURA        N =  11        PREDATOR SPECIES =  4
 54.5  %     SOLASTER STIMPSONI
 18.2  %     NEPHTYS SP
 18.2  %     PYCNOPODIA HELIANTHOIDES
 9.1   %     TELMESSUS CHEIRAGONUS

CRUSTACEA      N =  240       PREDATOR SPECIES =  14
 39.6  %     EVASTERIAS TROSCHELII
 30    %     LEPTASTERIAS HEXACTIS
 10.8  %     NUCELLA LAMELLOSA
 7.9   %     ELASSOCHIRUS GILLI
 3.8   %     LEPTASTERIAS POLARIS ACERVATA
```

APPENDIX K (Continued)

GASTROPODA N = 74 PREDATOR SPECIES = 11

67.6 %	LEPTASTERIAS HEXACTIS
10.8 %	EVASTERIAS TROSCHELII
5.4 %	PYCNOPODIA HELIANTHOIDES
2.7 %	PAGURIDAE UNID
2.7 %	OCTOPUS SP

PELECYPODA N = 482 PREDATOR SPECIES = 20

51.5 %	EVASTERIAS TROSCHELII
20.5 %	PYCNOPODIA HELIANTHOIDES
10.8 %	NUCELLA LAMELLOSA
8.1 %	ORTHASTERIAS KOEHLERI
3.3 %	LEPTASTERIAS HEXACTIS

POLYPLACOPHORA N = 14 PREDATOR SPECIES = 8

35.7 %	LEPTASTERIAS HEXACTIS
14.3 %	CROSSASTER PAPPOSUS
14.3 %	STRONGYLOCENTROTUS DROBACHIENSIS
7.1 %	FLIES UNID
7.1 %	METRIDIUM SENILE

ECTOPROCTA N = 15 PREDATOR SPECIES = 4

46.7 %	ELASSOCHIRUS GILLI
33.3 %	CROSSASTER PAPPOSUS
13.3 %	PTERASTER TESSELATUS
6.7 %	STRONGYLOCENTROTUS DROBACHIENSIS

ASTEROIDEA N = 3 PREDATOR SPECIES = 3

33.3 %	PYCNOPODIA HELIANTHOIDES
33.3 %	SOLASTER DAWSONI
33.3 %	SOLASTER STIMPSONI

ECHINOIDEA (STRONGYLOCENTROTUS SPP) N = 56 PREDATOR SPECIES = 8

75 %	PYCNOPODIA HELIANTHOIDES
12.5 %	ELASSOCHIRUS GILLI
3.6 %	FUSITRITON OREGONENSIS
1.8 %	CRIBRINOPSIS SIMILIS
1.8 %	ACTINIARIA UNID

HOLOTHUROIDEA N = 19 PREDATOR SPECIES = 5

36.8 %	LEPTASTERIAS HEXACTIS
31.6 %	SOLASTER STIMPSONI
10.5 %	DERMASTERIAS IMBRICATA
10.5 %	PYCNOPODIA HELIANTHOIDES
10.5 %	SOLASTER DAWSONI

OPHIUROIDEA N = 6 PREDATOR SPECIES = 1

100 %	ELASSOCHIRUS GILLI

TUNICATA N = 3 PREDATOR SPECIES = 3

33.3 %	FUSITRITON OREGONENSIS
33.3 %	ORTHASTERIAS KOEHLERI
33.3 %	SOLASTER STIMPSONI

APPENDIX K (Continued)

PISCES		N = 5	PREDATOR SPECIES = 4*
40	%	AMPHISSA SP	
20	%	BUCCINUM SP	
20	%	FUSITRITON OREGONENSIS	
20	%	OCTOPUS SP	

* - does not include vertebrate predator data

APPENDIX L SUMMARY OF PREDATOR SPECIES AND THEIR MAJOR PREY

```
NEMERTEA UNID      N =  1   PREY SPECIES =  1
 100   %    SABELLIDAE UNID

PARANEMERTES SP    N =  1   PREY SPECIES =  1
 100   %    PLATYNEREIS BICANICULATA

FLIES UNID  N =  1          PREY SPECIES =  1
 100   %    SCHIZOPLAX BRANDTII

METRIDIUM SENILE   N =  2   PREY SPECIES =  2
 50    %    MYTILUS EDULIS
 50    %    KATHARINA TUNICATA

TEALIA CRASSICORNIS         N =  2   PREY SPECIES =  2
 50    %    PENTIDOTEA WOSNESENSKII
 50    %    BALANUS GLANDULA

CRIBRINOPSIS SIMILIS        N =  2   PREY SPECIES =  2
 50    %    TELMESSUS CHEIRAGONUS
 50    %    STRONGYLOCENTROTUS DROBACHIENSIS

ACTINIARIA UNID    N =  1   PREY SPECIES =  1
 100   %    STRONGYLOCENTROTUS DROBACHIENSIS

NEREIS SP   N =  1          PREY SPECIES =  1
 100   %    GAMMARIDAE UNID

NEPHTYS SP  N =  11         PREY SPECIES =  4
 63.6  %    NOT FEEDING
 18.2  %    ECHIURUS ECHIURUS
 9.1   %    PLANT UNID
 9.1   %    POLYCHAETA UNID

AMPHIPODA UNID     N =  1   PREY SPECIES =  1
 100   %    ALARIA FISTULOSA

ELASSOCHIRUS GILLI          N =  95  PREY SPECIES =  25
 16.8  %    TISSUE UNID
 11.6  %    SAND UNID
 8.4   %    FORAMINIFERA UNID
 7.4   %    CRUSTACEAN UNID
 6.3   %    FLUSTRELLA SP

PUGETTIA GRACILIS N =  1    PREY SPECIES =  1
 100   %    NUDIBRANCH UNID

GAMMARIDAE UNID    N =  1   PREY SPECIES =  1
 100   %    ALARIA FISTULOSA

PAGURIDAE UNID     N =  3   PREY SPECIES =  3
 33.3  %    NEPHTYS SP
 33.3 %    FUSITRITON OREGONENSIS
 33.3 %    NEPTUNEA SP

TELMESSUS CHEIRAGONUS      N =  2   PREY SPECIES =  2
 50    %    BONELLIOPSIS SP
 50    %    MACOMA SP

ELASSOCHIRUS TENUIMANUS    N =  2   PREY SPECIES =  1
 100   %    SABELLIDAE UNID

CANCER MAGISTER   N =  4   PREY SPECIES =  4
 25    %    TISSUE UNID
 25    %    CIRRIPEDIA UNID
 25    %    GAMMARIDAE UNID
 25    %    PELECYPODA UNID

CHIONOECETES BAIRDI        N =  1   PREY SPECIES =  1
 100   %    TRESUS CAPAX

HYAS LYRATUS      N =  1   PREY SPECIES =  1
 100   %    MYTILUS EDULIS

SCYRA ACUTIFRONS  N =  1   PREY SPECIES =  1
 100   %    SAXIDOMUS GIGANTEA

TROPHONOPSIS LASIUS        N =  1   PREY SPECIES =  1
 100   %    MODIOLUS MODIOLUS

VOLUTHARPA AMPULLACEA      N =  1   PREY SPECIES =  1
 100   %    MODIOLUS MODIOLUS

AMPHISSA SP N =  2         PREY SPECIES =  1
 100   %    MYOXOCEPHALUS POLYACANTHOCEPHALUS

BUCCINUM SP N =  1         PREY SPECIES =  1
 100   %    MYOXOCEPHALUS POLYACANTHOCEPHALUS

DENDRONOTUS DALLI N =  6   PREY SPECIES =  2
 83.3  %    ABIETINARIA VARIABILIS
 16.7  %    ABIETINARIA SP

LACUNA SP   N =  1         PREY SPECIES =  1
 100   %    ALARIA FISTULOSA

FUSITRITON OREGONENSIS     N =  7   PREY SPECIES =  6
 28.6  %    STRONGYLOCENTROTUS DROBACHIENSIS
 14.3  %    MODIOLUS MODIOLUS
 14.3  %    SAXIDOMUS GIGANTEA
 14.3  %    CRYPTOCHITON STELLERI
 14.3  %    CNEMIDOCARPA FINMARKIENSIS

NATICA CLAUSA     N =  1   PREY SPECIES =  1
 100   %    MACOMA SP
```

APPENDIX L (Continued)

```
NUDIBRANCH UNID   N =  1   PREY SPECIES =  1
 100    %    ABIETINARIA SP

LITTORINA SITKANA N =  1   PREY SPECIES =  1
 100    %    PORPHYRA SP

ARCHIDORIS MONTEREYENSIS   N =  1   PREY SPECIES =  1
 100    %    HALICHONDRIA PANICEA

VOLUTHARPA SP     N =  2   PREY SPECIES =  1
 100    %    PENTIDOTEA SP

SIPHONARIA THERSITES       N =  1   PREY SPECIES =  1
 100    %    FUCUS DISTICHUS

NUCELLA LAMELLOSA N =  80  PREY SPECIES =  5
 65     %    MYTILUS EDULIS
 21.3   %    BALANUS SP
 10     %    BALANUS CARIOSUS
 2.5    %    UNID PREY
 1.3    %    BALANUS NUBILUS

SEARLESIA DIRA    N =  1   PREY SPECIES =  1
 100    %    POLYCHAETA UNID

NATICA SP   N =  1         PREY SPECIES =  1
 100    %    MACOMA BALTHICA

AEOLIDIDA UNID    N =  1   PREY SPECIES =  1
 100    %    HYBOCODON PROLIFER

NUCELLA EMARGINATA         N =  4   PREY SPECIES =  3
 50     %    BALANUS GLANDULA
 25     %    BALANUS SP
 25     %    MYTILUS EDULIS

KATHARINA TUNICATA         N =  5   PREY SPECIES =  1
 100    %    ALARIA SP

OCTOPUS SP  N =  3         PREY SPECIES =  3
 33.3   %    FUSITRITON OREGONENSIS
 33.3   %    NEPTUNEA LYRATA
 33.3   %    PHOLIS LAETA

OCTOPUS RUBESCENS N =  1   PREY SPECIES =  1
 100    %    CANCER OREGONENSIS

CROSSASTER PAPPOSUS        N =  14  PREY SPECIES =  11
 14.3   %    POLYPLACOPHORA UNID
 14.3   %    ECTOPROCTA UNID
 7.1    %    HYDROZOA UNID
 7.1    %    ABIETINARIA SP
 7.1    %    ROSTANGA PULCHRA
```

APPENDIX L (Continued)

```
DERMASTERIAS IMBRICATA     N =  73  PREY SPECIES =  9
 68.5  %    METRIDIUM SENILE
 9.6   %    PORIFERA UNID
 9.6   %    TEALIA CRASSICORNIS
 4.1   %    HYDROZOA UNID
 2.7   %    CUCUMARIA SP

EVASTERIAS TROSCHELII      N =  809 PREY SPECIES =  20
 53.8  %    NOT FEEDING
 19.7  %    MODIOLUS MODIOLUS
 6.6   %    BALANUS CRENATUS
 4.6   %    MYTILUS EDULIS
 2.7   %    BALANUS CARIOSUS

ORTHASTERIAS KOEHLERI      N =  83  PREY SPECIES =  13
 38.6  %    NOT FEEDING
 32.5  %    MODIOLUS MODIOLUS
 7.2   %    HUMILARIA KENNERLYI
 3.6   %    MUSCULUS DISCORS
 2.4   %    BALANUS SP

PTERASTER TESSELATUS       N =  19  PREY SPECIES =  10
 21.1  %    PORIFERA UNID
 21.1  %    ESPERIOPSIS SP
 10.5  %    ESPERIOPSIS LAXA
 10.5  %    MYCALE HISPIDA
 10.5  %    ABIETINARIA SP

PYCNOPODIA HELIANTHOIDES   N =  167 PREY SPECIES =  18
 25.1  %    SAXIDOMUS GIGANTEA
 25.1  %    STRONGYLOCENTROTUS DROBACHIENSIS
 22.8  %    MODIOLUS MODIOLUS
 3.6   %    NOT FEEDING
 3     %    MYA SP

SOLASTER DAWSONI  N =  3   PREY SPECIES =  2
 66.7  %    CUCUMARIA SP
 33.3  %    EVASTERIAS TROSCHELII

SOLASTER STIMPSONI         N =  23  PREY SPECIES =  6
 30.4  %    NOT FEEDING
 26.1  %    BONELLIOPSIS SP
 21.7  %    CUCUMARIA SP
 8.7   %    ANTHOZOA UNID
 4.3   %    EVASTERIAS TROSCHELII

HENRICIA LEVIUSCULA        N =  2   PREY SPECIES =  2
 50    %    PORIFERA UNID
 50    %    CLIONA CELATA

HENRICIA SANGUINOLENTA     N =  9   PREY SPECIES =  2
 77.8  %    MYCALE LINGUA
 22.2  %    PORIFERA UNID
```

LEPTASTERIAS POLARIS N = 1 PREY SPECIES = 1

100 %	MODIOLUS MODIOLUS

LEPTASTERIAS POLARIS ACERVATA N = 24 PREY SPECIES = 15

29.2 %	BALANUS SP
12.5 %	MYA SP
8.3 %	MODIOLUS MODIOLUS
4.2 %	CISTENIDES GRANULATA
4.2 %	BALANUS GLANDULA

SPINULOSA UNID N = 1 PREY SPECIES = 1

100 %	TROPHON MULTICOSTATUS

LEPTASTERIAS HEXACTIS N = 181 PREY SPECIES = 21

29.3 %	BALANUS SP
17.1 %	LITTORINA SITKANA
16.6 %	NOT FEEDING
8.8 %	MYTILUS EDULIS
5 %	PENTIDOTEA WOSNESENSKII

STRONGYLOCENTROTUS DROBACHIENSIS N = 25 PREY SPECIES = 6

60 %	FUSITRITON OREGONENSIS
20 %	AGARUM CRIBROSUM
8 %	CRYPTOCHITON STELLERI
4 %	LAMINARIA GROENLANDICA
4 %	ALARIA FISTULOSA

STRONGYLOCENTROTUS SP N = 1 PREY SPECIES = 1

100 %	RHODOPHYTA UNID

STRONGYLOCENTROTUS PALLIDUS N = 2 PREY SPECIES = 2

50 %	LAMINARIA GROENLANDICA
50 %	AGARUM CRIBROSUM

Note: Data does not include vertebrate predators.

APPENDIX M SUMMARY OF PREDATOR GROUPS WITH MAJOR PREY SPECIES

NEMERTEA N = 2 PREY SPECIES = 2

50	%	SABELLIDAE UNID
50	%	PLATYNEREIS BICANICULATA

ANTHOZOA N = 7 PREY SPECIES = 6

28.6	%	STRONGYLOCENTROTUS DROBACHIENSIS
14.3	%	TELMESSUS CHEIRAGONUS
14.3	%	PENTIDOTEA WOSNESENSKII
14.3	%	BALANUS GLANDULA
14.3	%	MYTILUS EDULIS

POLYCHAETA N = 12 PREY SPECIES = 5

58.3	%	NOT FEEDING
16.7	%	ECHIURUS ECHIURUS
8.3	%	PLANT UNID
8.3	%	POLYCHAETA UNID
8.3	%	GAMMARIDAE UNID

CRUSTACEA N = 112 PREY SPECIES = 37

15.2	%	TISSUE UNID
9.8	%	SAND UNID
7.1	%	FORAMINIFERA UNID
6.3	%	CRUSTACEAN UNID
5.4	%	FLUSTRELLA SP

GASTROPODA N = 113 PREY SPECIES = 23

46.9	%	MYTILUS EDULIS
15.9	%	BALANUS SP
7.1	%	BALANUS CARIOSUS
4.4	%	ABIETINARIA VARIABILIS
3.5	%	MYOXOCEPHALUS POLYACANTHOCEPHALUS

POLYPLACOPHORA N = 5 PREY SPECIES = 1

100	%	ALARIA SP

CEPHALAPODA (OCTOPUS SPP) N = 4 PREY SPECIES = 4

25	%	CANCER OREGONENSIS
25	%	FUSITRITON OREGONENSIS
25	%	NEPTUNEA LYRATA
25	%	PHOLIS LAETA

ASTEROIDEA N = 890 PREY SPECIES = 87*

25.5	%	MODIOLUS MODIOLUS
9	%	BALANUS SP
6.1	%	BALANUS CRENATUS
6.1	%	MYTILUS EDULIS
5.6	%	METRIDIUM SENILE

* - does not include 'not feeding' data

APPENDIX M (Continued)

ASTEROIDEA N = 1513 PREY SPECIES = 89

40.4	%	NOT FEEDING
15	%	MODIOLUS MODIOLUS
5.3	%	BALANUS SP
3.6	%	BALANUS CRENATUS
3.6	%	MYTILUS EDULIS

ECHINOIDEA (STRONGYLOCENTROTUS SPP) N = 28 PREY SPECIES = 7

53.6	%	FUSITRITON OREGONENSIS
21.4	%	AGARUM CRIBROSUM
7.1	%	LAMINARIA GROENLANDICA
7.1	%	CRYPTOCHITON STELLERI
3.6	%	ALARIA FISTULOSA

PICES N = 318 PREY SPECIES = 102

10.1	%	GAMMARIDAE UNID
5.7	%	EGGS UNID
3.5	%	PELECYPODA UNID
2.8	%	HIPPOLYTIDAE UNID
2.8	%	CLADOCERA UNID

AVES N = 55 PREY SPECIES = 12

72.7	%	STRONGYLOCENTROTUS DROBACHIENSIS
7.3	%	MACOMA BALTHICA
3.6	%	MODIOLUS MODIOLUS
1.8	%	BRACHYURA UNID
1.8	%	BALANUS SP

APPENDIX N-1 ABUNDANCE DATA FOR MUD BAY; 10 JULY 1978. 0.5 x 10 M^2 CONTIGUOUS QUADRATS FROM 10.7 M BELOW MLLW

TAXA	Frequency					$\bar{x} \pm s$	Density (no./m^2)
INVERTEBRATA							
Abietinaria spp	3	2	3	1	0	1.8 ± 1.3	0.4
Balanus rostratus (patches)	0	2	2	1	2	1.0 ± 1.0	0.2
Chionoecetes bairdi	0	0	0	0	2	0.4 ± 0.9	0.1
Labidochirus splendescens	1	1	3	7	2	2.8 ± 2.5	0.6
Metridium senile	0	3	0	0	0	0.6 ± 1.3	0.1
Neptunea lyrata	0	0	0	1	0	0.2 ± 0.4	0.04
Pagurus capillatus	0	3	0	1	0	0.8 ± 1.3	0.2
Ptilosarcus gurneyi (juvenile)	0	1	0	0	0	0.2 ± 0.4	0.04
Tubularia sp	0	0	1	0	0	0.2 ± 0.4	0.04
CHORDATA							
Cottidae, unid., small	0	0	0	2	0	0.4 ± 0.9	0.1
Pleuronectiformes, unid. (juvenile)	1	0	1	1	1	0.8 ± 0.4	0.2

EXTRALIMITAL SPECIES:

INVERTEBRATA

Asterias amurensis
Evasterias troschelii
Fusitriton oregonensis
Oenopota spp
Pagurus aleuticus
P. ochotensis
Phyllochaetopterus sp
Pugettia gracilis

Substrate: Flat mud bottom with scattered, sparse boulders and shell debris

APPENDIX N-2 ABUNDANCE DATA FOR MUD BAY; 10 JULY 1978. 0.5 x 5 M^2 CONTIGUOUS QUADRATS FROM 10.7 M BELOW MLLW

TAXA	Frequency																		$\bar{x}$ ± s	Density (no./m^2)
INVERTEBRATA																				
Chionoecetes bairdi	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1 ± 0.2	0.02
Metridium senile	1	0	0	0	0	0	1	1	1	2	0	0	0	0	0	0	0	0	0.3 ± 0.6	0.13
Neptunea lyrata	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	0.04
Neptunea egg case	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	-	-
Ptilosarcus gurneyi	0	0	1	1	0	0	-	-	-	-	-	-	-	-	-	-	-	-	0.3 ± 0.5	0.13
Pugettia gracilis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1 ± 0.2	0.02
Telmessus cheiragonus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.2	0.02
CHORDATA																				
Lepidopsetta bilineata	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2 ± 0.5	0.07
Pleuronectiformes unid.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0.1 ± 0.2	0.02
Fish, unid.,elongate	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1 ± 0.2	0.02

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BEST DOCUMENT AVAILABLE

APPENDIX N-3 ABUNDANCE DATA FOR SELECTED SPECIES FROM MUD BAY; 10 JULY 1978

TAXA	Frequency											$\bar{x}$ ± s	Density (no./m^2)
INVERTEBRATA													
Chionoecetes bairdi						2						-	0.1

Quadrat Size (m): 0.5 x 50
Depth below MLLW (m): 10.7
Substrate: Flat mud bottom with scattered, sparse boulders and shell debris

Oenopota spp	4	3	1	1	3	0	4	1	1	3	4	2.3 ± 1.5	9.1

Quadrat Size (m): ½ x ½
Depth below MLLW (m): 11.3

EXTRALIMITAL SPECIES:

INVERTEBRATA

Admete couthoyi
Chionoecetes bairdi
Metridium senile
Neptunea lyrata
Nuculana hamata
Odostomia sp
Oenopota alaskensis
O. alitakensis
O. bicarinata
O. incisula
O. solida
O. turricula cf. *rugulata*
O. sp H
Ptilosarcus gurneyi - few, juvenile

CHORDATA

Bathymaster sp
Lepidopsetta bilineata
Pleuronectiformes, unid., juv.

APPENDIX O-1 RECONNAISSANCE SURVEY FOR COTTONWOOD BAY; 13 JUNE 1978, LESS THAN 1.5 M BELOW MLLW

TAXA	Substrate code a	b	c	d	e	f
ALGAE - Chlorophyta						
Chlorophyta, unid., filamentous			X	X	X	
Monostroma sp			X	X		
ALGAE - Phaeophyta						
Laminaria saccharina					X	X
Pylaiella littoralis			X	X	X	
ALGAE - Rhodophyta						
Rhodophyta, unid., filamentous			X	X		
PORIFERA						
Porifera, unid., orange				X		X
CNIDARIA - Anthozoa						
Anthopleura artemisia				X		X
ANNELIDA - Polychaeta						
Cistenides sp		X				
Nephtys sp					X	
ECHIURA						
?*Echiurus echiurus*					X	
Bonelliopsis		X				

TAXA	Substrate code a	b	c	d	e	f
ARTHROPODA - Crustacea						
Balanus sp						X
Pagurus ochotensis					X	X
Pagurus sp						X
Telmessus cheiragonus	X			X	X	
MOLLUSCA - Gastropoda						
?*Acanthodoris* sp						X
MOLLUSCA - Pelecypoda						
Clinocardium nuttalli	X	X			X	X
Macoma balthica shells		X				
M. ?*obliqua* shells		X				
Mya priapus shells		X				
Mya sp	X	X			X	X
Panomya ampla					X	
ECTOPROCTA						
Caulibugula sp					X	X
ECHINODERMATA - Asteroidea						
Leptasterias polaris acervata		X				X
CHORDATA - Pisces						
Hexagrammos stelleri						X
Lepidopsetta bilineata						X
Pleuronectiformes, juv.		X				

Depth (m) below MLLW: a - d = 0.6
e - f = 1.5

Substrate: a = W. of camp, mud
b = " " ", sand
c = " " ". gravel band
d = Offshore from OCS camp, silty sand with scattered boulders, cobble
e = " , " " ", sand/mud flat
f = E. of camp, sandy cobble, mud and silty areas with rocks

APPENDIX O-2 ABUNDANCE DATA FOR SELECTED SPECIES FROM COTTONWOOD BAY SUBTIDAL AREA; 13 JUNE 1978. ¼ M^2 SQUARE QUADRATS FROM LESS THAN 1.5 M BELOW MLLW

TAXA						$\bar{x} \pm s$	Density (no./m^2)
MOLLUSCA - Pelecypoda							
Clinocardium nuttallii	0	0	0	6	6	2.4 ± 3.3	9.6
Mya spp	5	3	1	1	0	2.0 ± 2.0	8.0

APPENDIX P-1 ANIMAL ABUNDANCE DATA FOR OIL BAY SUBTIDAL AREA; 4 AUGUST 1978. 0.5 X 30 M^2 BAND TRANSECTS FROM 1.2 M BELOW MLLW

TAXA	Frequency		$\bar{x} \pm s$	Density (no./m^2)
Siliqua patula	1	1	1.0 ± 0.0	0.07
Telmessus cheiragonus	0	1	0.5 ± 0.7	0.03
Pleuronectiformes, unid.	0	1	0.5 ± 0.7	0.03

EXTRALIMITAL SPECIES:

INVERTEBRATA
- *Pagurus* sp
- *Spisula polynyma*

CHORDATA - Pisces
- *Isopsetta isolepis*
- *Lumpenus sagitta*

Substrate: Fine, silty sand with ripple marks, moderate organic debris

APPENDIX P-2 RECONNAISSANCE SURVEY FROM OIL BAY SUBTIDAL AREA; 4 AUGUST 1978

TAXA

ANNELIDA - Polychaeta

Polychaeta, unid.

ARTHROPODA - Crustacea

Crangon sp
Cumacea, unid.
Gammaridea, unid.

TAXA

MOLLUSCA - Pelecypoda

Siliqua patula

CHORDATA - Pisces

Lepidopsetta bilineata
Pleuronectiformes, unid.

Depth below MLLW (m): 1.7 - 2.7

Substrate: Silty sand, firm with ripple marks

APPENDIX V

THESIS - FEEDING HABITS OF CRANGONID SHRIMPS AND SOME ASPECTS OF SEDIMENT-DETRITAL FOOD SYSTEMS IN LOWER COOK INLET, ALASKA

FEEDING HABITS OF CRANGONID SHRIMPS AND SOME ASPECTS OF SEDIMENT-DETRITAL FOOD SYSTEMS IN LOWER COOK INLET, ALASKA

A

THESIS

Presented to the Faculty of the
University of Alaska in partial fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE

By
Randy L. Rice, B.A. (Honors)
Fairbanks, Alaska
May 1980

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ABSTRACT

Feeding habits of crangonid shrimps and certain aspects of their relationship with the sediment-detrital food system in Cook Inlet, Alaska, were investigated from 1977 to 1979. A wide variety of prey items were utilized including small crustaceans (35% frequency of occurrence) and polychaetes (24% frequency of occurrence). After digestion of organic constituents, the inorganic sediment component averaged 55% of the stomach contents on a dry weight basis. Sediment contained up to 14.5 mg organic carbon per gram sediment. Respiration rate of *Crangon dalli* averaged 25.7 μl O_2 g^{-1} hr^{-1}. The daily percent energy potential available to crangonids from sediment-detrital and bacterial carbon was estimated. On stations examined this potential ranged from 4.3% to 18.6% for sediment total organic carbon and up to 5.3% for the bacterial carbon fraction. A theoretical maximum potential of 40% of daily energy needs from sediment total organic carbon and 17.4% from the bacterial carbon fraction was calculated. Although crangonids in this area cannot meet all of their energy needs by ingestion of sediment, sediment carbon may be supplemental to an opportunistic feeding style. This may enhance their ability to survive in a wide range of habitats. Feeding habits of crangonid shrimp and sediment-detrital quality was observed to be related to previously described oceanographic conditions in Cook Inlet.

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INTRODUCTION

Sediment-detrital food systems are currently an area of intensive research (Baker and Bradnam, 1976; Fenchel and Jørgensen, 1977; Kofoed, 1975, Rieper, 1978; Tenore, 1975; 1977). A significant number of benthic dwelling invertebrates meet their energetic needs by ingestion of sediment enriched with bacteria and detritus to varying degrees. Of interest is the importance of bacteria in the nutrition of these detrital feeding animals. For instance, it has been demonstrated that some detrital feeding animals assimilate estuarine detritus and its associated bacteria (Adams and Angelovic, 1970) and growth efficiency is in some cases higher when bacteria enriched food sources are included in the diet (Kofoed, 1975). Further, some authors feel that bacteria may play a central role in the energetic pathways of these food systems (Fenchel and Jørgensen, 1977).

It is of interest to examine the dynamics of detrital food systems in oil and natural gas producing areas, such as Cook Inlet, Alaska, where hydrocarbons may become associated with sediments. Oil and gas exploitation and related potential disturbances in Alaska waters has led to a series of studies by the Outer Continental Shelf Environmental Assessment Program (OCSEAP). In Cook Inlet, Alaska, studies have established baseline data on distribution, abundance, and trophic relationships of nearshore benthic communities (Feder *et al.*, 1980), microbial activity (Griffiths and Morita, 1979), and sedimentation characteristics (Larrance, 1979).

The Study Area - Cook Inlet, Alaska

Cook Inlet is a positive, partially-mixed estuary located north of the Gulf of Alaska in the southcentral portion of the state in an area surrounded by mountains and glaciers (Figure 1). The inlet is some 370 km long in a northeast-southwest direction, and 139 km in width at the mouth. The average depth is approximately 60 m with depths to 200 m at the mouth. For the purposes of this report, "lower" Cook Inlet encompasses the area from Cape Douglas in the south to Chinitna Bay in the north. Other authors typically consider the forelands region as the northern limit of "lower" Cook Inlet (Burbank, 1974).

Circulation in the inlet has been previously described (Burbank, 1977). Circulation is thought to be primarily tidal, modified by the Coriolis effect and morphology of the basin. Currents to 6.5 kts may be generated by tides. Oceanic water enters the inlet from the east via the Alaska Current. Water is carried into the inlet on flood tides and flows north along the eastern half of the upper inlet. On the ebb tide relatively fresh silt-laden water from the upper inlet is carried out along the western shores. Incoming oceanic water has been characterized as saline (32°/$_{\circ\circ}$) relative to the out-flowing water (28-29°/$_{\circ\circ}$). The water column is well mixed along the eastern shore from the southern tip of the Kenai Peninsula north. Along the western shore the fresh water outflow stratifies on top of more saline water. Fresh water input to the inlet is supplied primarily by the Susitna River and Knik Arm at the head of the inlet. The influence of wind on the general circulation of the inlet is not fully understood. Burbank (1977) has

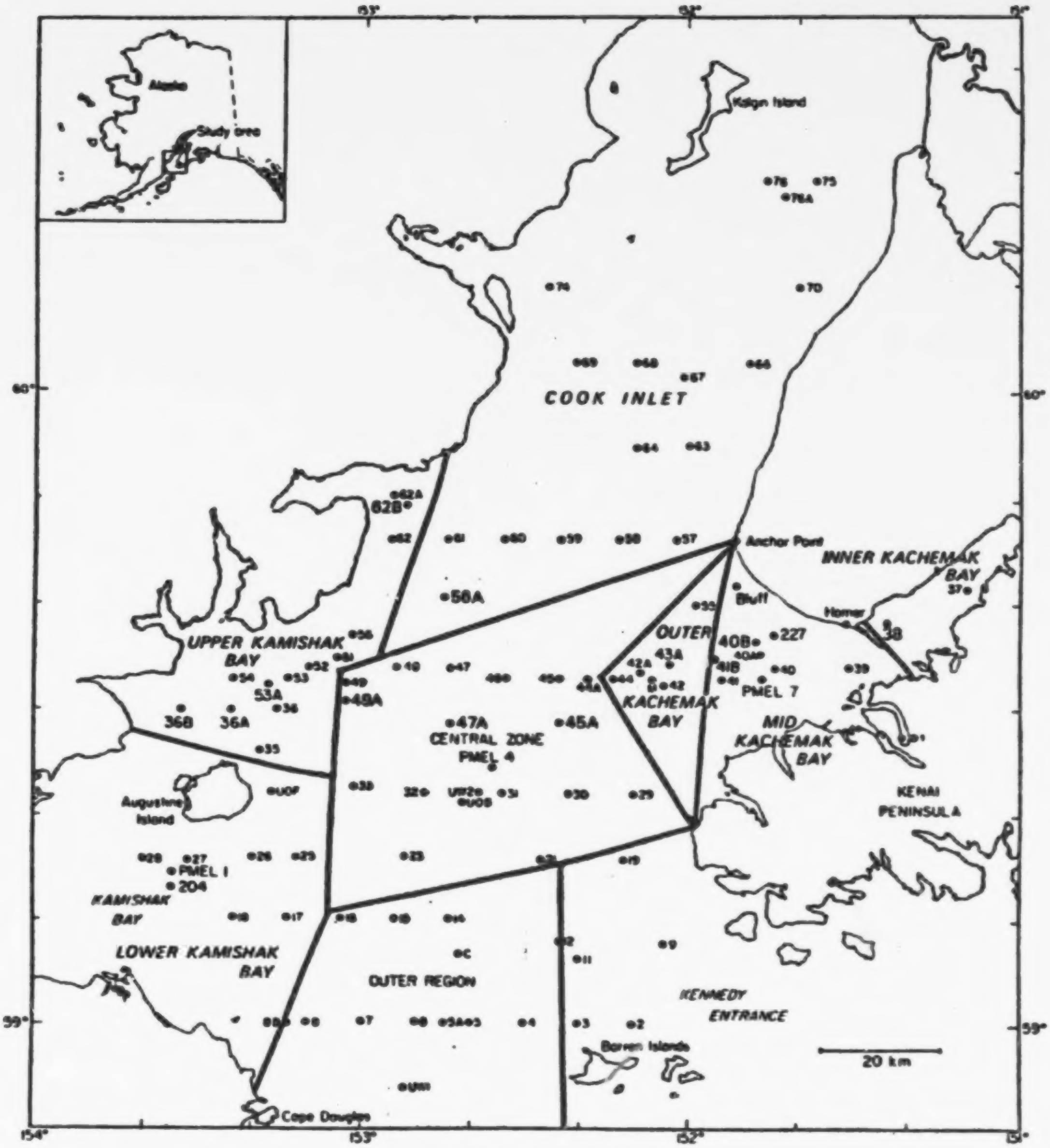
Alaska
Study area
Kalgin Island
COOK INLET
Anchor Point
INNER KACHEMAK BAY
Bluff
Homer
OUTER KACHEMAK BAY
MID KACHEMAK BAY
UPPER KAMISHAK BAY
CENTRAL ZONE
PMEL 4
PMEL 7
PMEL 1
Augustine Island
KAMISHAK BAY
LOWER KAMISHAK BAY
OUTER REGION
KENNEDY ENTRANCE
Barren Islands
Cape Douglas
KENAI PENINSULA
20 km
76
75
76A
74
70
69
68
67
66
64
63
62A
62B
62
61
60
59
58
57
58A
56
55
54
53
53A
52
51
49
49A
47
47A
45A
43A
42A
42
40B
227
41B
40
39
38
37
36
36B
36A
35
33
32
31
30
29
28
27
26
25
23
21
19
18
17
16
15
14
12
11
9
8
7
6
5
4
3
2
204
C
153°
152°
151°
154°
60°
59°

Figure 1. Lower Cook Inlet Benthic Stations. (Feder *et al.*, 1980).

prepared a generalized net surface circulation scheme in lower Cook Inlet (Figure 2).

Two important features and areas of specific interest in lower Cook Inlet are Kamishak and Kachemak Bays. These are areas of high biological activity and are important to commercial fisheries (Burbank, 1977; Crow, 1977; Feder *et al.*, 1980; Rice *et al.*, 1980). Gyre systems are present in inner and outer Kachemak Bay at least for part of the year. Eddies and gyres are also suggested in the Augustine Island, Kamishak Bay area from drift card studies, although little additional information is available for this area (Burbank, 1977). During stormy periods (September-November) the gyres may break down. Residence time of water in the outer Kachemak Bay gyre system has been estimated at 15 days, with the source of this water perhaps upwelling near Elizabeth Island. This rich water may in part account for high primary production observed in the Kachemak Bay region. Larrance (1979) reports values to 7.8 g m^{-2} day^{-1} primary production for Kachemak Bay and 6.8 g m^{-2} day^{-1} for Kamishak Bay.

Sediments in lower Cook Inlet have been characterized as facies 3, sand with variable amounts of gravel (Sharma and Burrell, 1970). It was noted that finer material is deposited in Kamishak Bay. Feder (personal communication) has noted similar patterns of patchiness of sand and clays observed in benthic grab studies. Muds and clays predominate in inner and outer Kachemak Bay, as well as in Kamishak, with coarser sands observed in middle inlet and western stations.

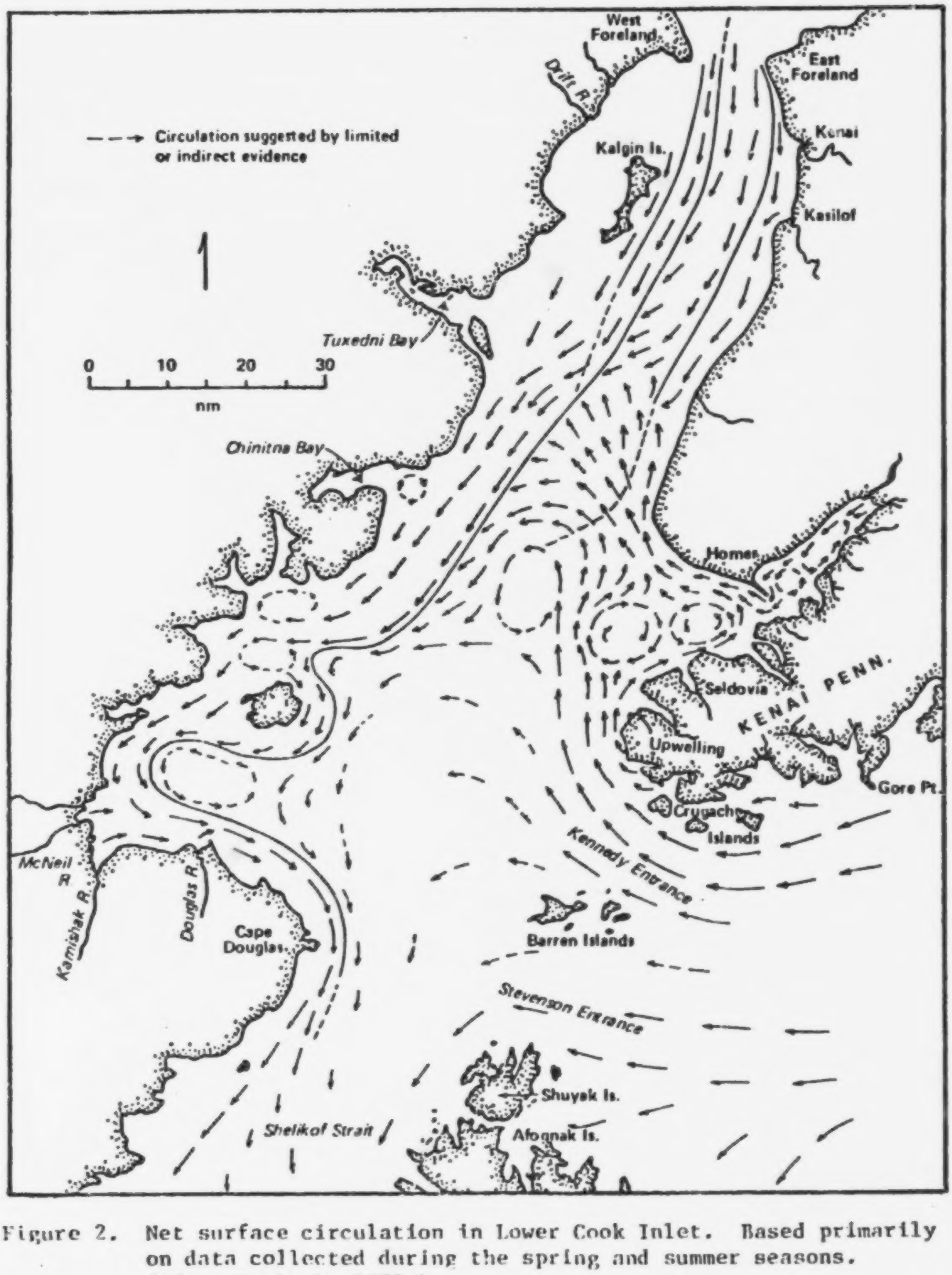
West Foreland
East Foreland
Drift R.
Circulation suggested by limited or indirect evidence
Kalgin Is.
Kenai
Kasilof
Tuxedni Bay
0
10
20
30
nm
Chinitna Bay
Homer
Seldovia
KENAI PENN.
Upwelling
Gore Pt.
Chugach Islands
Kennedy Entrance
McNeil R.
Kamishak R.
Douglas R.
Cape Douglas
Barren Islands
Stevenson Entrance
Shuyak Is.
Afognak Is.
Shelikof Strait

Figure 2. Net surface circulation in Lower Cook Inlet. Based primarily on data collected during the spring and summer seasons. (After Burbank, 1977.)

Potential sources of detrital inputs to the bottom include phytoplankton primary production, macroalgae, and terrestrial runoff. From phytoplankton sources, Larrance (1979) estimates 60 g C m^{-2} (Kachemak Bay), 40 g C m^{-2} (Kamishak Bay) and 17 g C m^{-2} (central inlet) were delivered to the bottom over a 4 month period. Data are not available for macrophyte inputs in lower Cook Inlet but are potentially significant in places. Mann (1972) noted the importance of macrophyte production in detritus food chains. The term detritus used in this report includes dissolved sources, egestion, secretion, etc., from within and without of the system (see Fenchel and Jørgensen, 1977; Wetzel *et al.*, 1972). The detrital food chain is then any pathway by which energy derived from detrital organic carbon becomes available to the biota.

Crangonid Shrimp

The crangonid shrimps are one of the dominant benthic invertebrates encountered in lower Cook Inlet (Feder *et al.*, 1980). In these waters there are three genera representing the family Crangonidae: *Crangon*, *Sclerocrangon*, and *Nectocrangon (Argis)*. Rathburn *et al.* (1910) give taxonomic and occurrence information for the various species in northern waters. From trawling operations in lower Cook Inlet it appears *Crangon dalli*, *Crangon franciscorum*, and *Crangon communis* are by far the most common crangonids present (Feder *et al.*, 1980). Crangonids frequently represent 20% of the animals counted in trawl catches.

Observations on trophic relationships showed crangonids to be a major food resource for many predators. Crangonids are frequently observed in the stomachs of demersal fishes such as flathead sole, pollock, and Pacific cod (Feder *et al.*, 1980), and in snow crab (Paul *et al.*, 1979). Crangonid shrimps are considered to be important in the benthic ecosystem because of their widespread distribution and abundance and their importance as a food resource by members of the Cook Inlet food chain.

Little was known of crangonid feeding habits at the outset of this study. Initial microscopic observations of crangonid stomachs showed large amounts of sediment and detritus. Additionally, these early observations revealed that prey taken by crangonids, such as the clam *Macoma*, were often themselves sediment-detrital feeders. Crangonids may occupy a unique trophic position, perhaps serving as mediators between the sediment-detrital system and epibenthic and free-swimming predators.

To clarify the position of crangonids an investigation of the feeding ecology of these shrimp was undertaken. Specifically, the following questions were addressed.

1. What prey organisms are utilized?
2. Is sediment frequently observed in shrimp gut contents? If so, how much?
3. Is detritus a frequently observed food component?
4. What magnitude energy source does sediment-detrital and bacterial carbon represent relative to the needs of these shrimps?
5. What relationships exist between crangonid shrimp feeding habits and oceanographic characteristics of the system?

In an attempt to answer these questions, the following investigations were initiated:

1. Detailed and extensive gut sample analysis of lower Cook Inlet crangonid shrimp for frequency of prey data;
2. quantitative investigation of gut sediment content;
3. potential nutritive value of sediments, including organic carbon, and microbial biomass; and
4. metabolic rate evaluation of crangonid shrimp by measurement of respiration.

METHODS

Specimens of *Crangon dalli*, *Crangon franciscorum*, and *Crangon communis* were collected in lower Cook Inlet on six cruises from November 1977 to August 1978. Shrimp were obtained with small otter and Agassiz trawls. Depth ranged from 22 to 150 m on the stations where shrimp were taken.

For detailed gut analysis, shrimp were preserved in 10% buffered formalin. Specimens were first examined under a dissection microscope (60X) and large fragments and whole organisms identified. A subsample of the material was then placed on a slide and examined with a compound microscope (100X) and small fragments, polychaete setae, and diatoms were identified in this manner. Additional sampling with various dredges, grabs, and trawls captured potential prey organisms and aided in the identification of fragments in the shrimp stomachs.

Quantitative determination of gut sediment content was done using the IBP methodology (Holme and McIntyre, 1971). Stomach contents were dissected from preserved specimens, dried at 60°C and weighed. The sample was then treated with 10% KOH at 100°C to remove organic matter. Subsequent treatments of the sample with concentrated HCl removed chitin and shell ($CaCO_3$) fragments. The sample was again dried and weighed. The weight of the remaining inorganic material was determined by difference. Microscopic examination of the residual material after this treatment showed that the remaining material was devoid of any tissue, organic matter, or chitin fragments. The inorganic fraction is indicative of the amount of sediment ingestion. Natural carbonates associated with the sediments are destroyed by this procedure hence the actual ingestion of Cook Inlet bottom material is underestimated. A control with known amounts of sand and tissue was evaluated using the above method.

Sediment samples taken by van Veen grab were frozen and later analyzed for carbon and nitrogen content on a Carlos Erba Elemental Analyzer (Model 1104). Sediment samples were weighed on a Mettler top loading balance E200, pulverized and homogenized, sieved through a 2 mm mesh screen, and rocks removed and weighed. The sample was dried overnight in a Thelco Model 28 forced air oven at 50°C. Samples were then weighed in triplicate into tin cups on a Cahn Rg electrobalance. The sample was then combusted at 1050°C using cyclohexanone as a standard. Larrance (1979) reports that on the average, 13% of the total carbon in sediment trap samples is from inorganic sources. Using this figure, organic carbon was computed for lower Cook Inlet stations sampled in this study.

Bacterial biomass of sediments was obtained from direct counts obtained by epifluorescence microscopy. Sediment samples (10 ml) were fixed in 1 ml of membrane-filtered (.45 µm) formaldehyde (37%). When a relatively high number of organisms was present, the samples were diluted with membrane-filtered seawater. Samples were filtered onto nucleopore filters with .2 µm pore size. The staining procedure used was that of Zimmerman and Meyer-Riel (1974). Bacterial cells were counted using a Zeiss IV Fl epifluorescence condenser microscope fitted with filters KP 500, KP 490, FT 510, and LP 520. The eyepiece used was KPT W 12.5X. Approximately 50 restriction fields were counted per sample. Only bodies with distinct fluorescence (either orange or green), clear outline and recognizable bacterial shape were counted as being bacterial cells. Using a value of 1×10^{-13} g as the amount of carbon per bacterial cell, the amount of bacterial carbon present in these sediments was calculated from the number of cells present as determined by the direct count method. Although a variety of values are available from the literature, this figure was recommended as appropriate for marine sediment mixed bacterial populations (M. J. Klug, personal communication). Bacterial carbon in 1 ml sample was converted to a dry weight basis using a factor determined in the laboratory by drying known volumes of sediments from the various stations.

Heterotrophic colony forming units (CFU's) were counted on Zobell's 2216E media containing peptone, 5.0 g; $FePO_4$, 0.1 g; yeast extract, 1.0 g;

Bacto-agar, 15.0 g; "aged" seawater, 1000 ml. Sediment was collected with a van Veen grab. In several cases plates were done from successive grabs at one station. The top 1-2 cm of sediment in a grab were removed and placed in sterile plastic bags (Nasco Whirl-Pak) until they could be processed. Plating was done at room temperature. Each dilution tube was mixed using a rotary mixer to facilitate removal of the bacteria from the sediment particles. 0.1 ml of 10^{-2} through 10^{-5} dilutions were plated. Five replicates were made at each dilution. Plates were incubated for approximately ten days after which colonies were counted using a Quebec Colony Counter. Dry sediment weights were determined by rinsing the 10^{-1} dilutions into pre-weighed beakers, drying them in a drying oven (105°C) for 24-48 hours and weighing the dry sediment. These weights were then used to calculate the viable count.

In order to evaluate the potential significance of bacterial carbon utilization relative to the metabolic demands of the animal, the base metabolic rate, or carbon demand of the shrimp was determined. This was achieved by a simple respirometer experiment. Shrimp were placed in individual flasks with 75 ml of seawater and a small amount of autoclaved sediment. Carbon dioxide evolved by the animal during the course of the procedure is trapped in 30% KOH and the Gilson respirometer measures the resultant decrease in volume. Temperature was maintained at 4.5°C during the course of the analysis (see Umbreit, 1964, for more on respirometry).

RESULTS

Food, Prey, Feeding Habits

Data are tabulated in Table 1 summarizing the frequency of occurrence information gathered on *Crangon dalli* from lower Cook Inlet. Sixty categories of food were observed in 863 individuals. The most important food items, based on the frequency of occurrence of identifiable remains in feeding shrimp, were Crustacea (unknown types) 35% frequency of occurrence, Polychaeta (unidentifiable types) 24%, Maldanidae 22%, and various types of diatoms (naviculoids 23%, Coscinodisceae 18%, and *Melosira* 26%). Unidentified organic matter (including animal tissue) was common, 32%, and sediment was observed in virtually all of the stomachs with contents, 90%. Further, 14 types of polychaete worms were identified with frequency of occurrence ranging from .4% to 10%. Unidentifiable bivalves were observed in 9% of the stomachs with contents, with 6 additional categories of identified clams infrequently observed in .6 to 1% of the samples with contents. In addition to the unidentified Crustacea 7 other crustacean categories were observed in .5 to 5% of the samples. Gastropoda 3%, Echinodermata 1%, and Porifera 2% were occasionally observed. Prey items observed in the stomach samples from the various stations typically reflect the more abundant organisms observed in grab and dredge samples at those stations. The prey observed, with few exceptions such as diatoms, are bottom dwelling organisms.

Though opportunism and generalist feeding behavior are the dominant feeding modes, active predation also took place in these animals as

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TABLE 1

Food of Cook Inlet Crangon dalli

[illegible]

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evidenced by type and quantity of contents in certain individual stomachs. For example, 4 intact *Nuculana* spp. (4-6 mm in size) were observed in one individual *Crangon dalli* stomach. It is noteworthy that both the high frequency of sediment and detritus, and the type of prey observed in crangonid stomachs suggest these shrimp rely heavily on the sediment-detrital food system for their nutritive needs. With few exceptions (e.g. Teleostei, diatoms, Polynoidae) the organisms utilized as food are themselves deposit feeding types such as *Lumbrineris*, Capetellidae, and *Nuculana*.

The time series sampling on Station 62 suggests the possibility of diurnal periodicity in feeding behavior. Figure 3 is a diagram of the frequency of occurrence of numbers of stomachs with and without contents in the sample with respect to time. The higher occurrence of stomachs with contents during daylight hours declining towards evening suggests the animals commence feeding at night.

Gut Inorganic Sediment Content

Data are summarized in Table 2 for the determination of quantity of sediment present in crangonid gut samples after digestion of organic matter by KOH. Samples typically contained more than 50% inorganic material on a dry weight basis. This amount, based on the contents of some 487 individuals was consistent, with the exception of samples from two stations, 40A and 18. The percentage of the sediment component estimated here is conservative, as controls with known amounts of sand and tissue showed the method underestimated sediment content 2-14%.

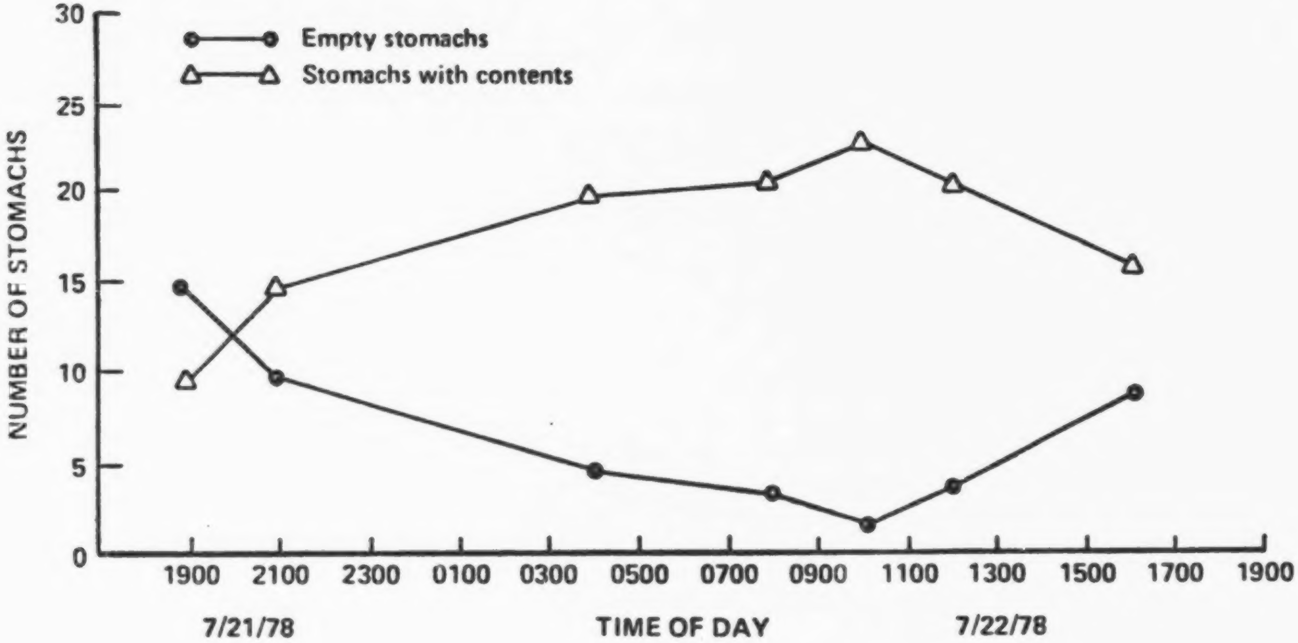

Figure 3. Feeding periodicity of *Crangon* on Station 62. Twenty-five stomachs were examined at each sampling time.

TABLE 2

Inorganic Sediment Component in Gut Contents of Lower Cook Inlet *Crangon*

Station/Animal	Date	Depth (m)	No. stomachs examined	No. stomachs with contents	dry wt. contents (g)	Dry wt. contents after KOH, HCL treatment (g)	$\bar{X}$ amt./ animal (g)[1]	% contents inorganic sediment component
40A - *Crangon dalli*	10 June 78 14 June 78	33	90	26	.699	.038	.001	5.4%
18 - *Crangon dalli*	10 June 78	53	27	15	.269	.019	.001	7.1%
35 - *Crangon dalli*	5 May 78	33	32	13	.078	.020	.002	25.6%
54 - *Crangon dalli*	14 May 78	22	91	60	.958	.907	.015	94.7%
PMEL 7 - *Crangon dalli*	20 Jul 78	85	51	35	.144	.111	.003	77.1%
PMEL 7 - *Crangon dalli*	14 Aug 78	85	178	94	.286	.179	.002	63.0%
PMEL 1 - *Crangon* spp.	20 Jul 78	33	80	51	.209	.139	.003	66.5%
62A - *Crangon dalli*	29 Mar 78	27	123	75	.651	.422	.005	64.8%
62A - *Crangon dalli*	31 Mar 78	27	72	54	.513	.238	.004	46.4%
62 - *Crangon dalli*	21 Jul 78	27	75	40	.345	.254	.006	74.0%
53 - *Crangon* spp.	11 Jun 78	89	20	13	.123	.091	.007	74.0%
27 - *Crangon dalli*	17 Jul 78	33	114	57	.423	.289	.005	70.4%

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[1] The average amount of the inorganic sediment component per animal is derived by division of the dry weight of contents after KOH digestion by the number of stomachs with contents.

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Microbial Biomass of Sediment

Results of the sediment microbial biomass analysis are depicted in Table 3. As indicated, there are very high numbers of microbial cells in these sediments. Sediment samples typically had 10^9-10^{10} cells ml^{-1}. In general, stations on the western side of the inlet (53, 27, 204, 62) had fewer cells than stations on the eastern side and Kachemak Bay area (PMEL 7, 37, 227).

Viable counts of some selected lower Cook Inlet stations are tabulated in Table 4. These values, ranging from 10^6-10^7 CFU g^{-1} dry weight are, as expected, lower than direct counts. On Station 37, 5.6×10^{10} cells g^{-1} were found by direct counts, compared to $\sim 1 \times 10^6$ CFU g^{-1} as determined by viable count methods. Similarly, 4.75×10^{10} cells g^{-1} (direct counts) on Station PMEL 7 is contrasted with 3.28×10^6 CFU g^{-1}.

Carbon Values of Sediments

Evaluation of total carbon content of lower Cook Inlet sediments revealed values ranging from .2 to 1.7% carbon (Table 5). On a dry weight basis, lower Cook Inlet samples contained from 1.2 (Station PMEL 4) to 16.7 (Station 40A) mg C g^{-1} sediment. Middle inlet and western stations (PMEL 4, 53, 8, PMEL 1) had less carbon than Kachemak Bay area samples (PMEL 7, 37, 40A). The computed organic carbon values range from 1.04 (Station PMEL 4) to 14.53 (Station 40A) mg g^{-1} sediment (Table 5). Kachemak Bay samples were higher in organic carbon than other regions in the inlet.

TABLE 3

Microbial Biomass of Cook Inlet Sediment Samples[1]

Station/Date	Direct Counts cells ml^{-1} sample	mg C g^{-1} sediment
53 - 18 Aug	5.0×10^{9}	.60
204 - Aug	1.9×10^{9}	.19
27 - Aug	3.9×10^{9}	.36
PMEL 1 - Aug	2.4×10^{10}	2.47
PMEL 1 - Aug	4.3×10^{10}	9.40
227 - Aug	3.4×10^{9}	.42
227 - Aug	8.0×10^{9}	1.00
62A - Aug	2.3×10^{9}	.18
62A - Aug	6.7×10^{9}	.53
37	4.3×10^{10}	6.20
37	3.5×10^{10}	5.10
PMEL 7 - Aug	3.8×10^{10}	4.80
PMEL 7 - Aug	4.6×10^{10}	5.80

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[1] Microscopic work accomplished by research group of R. Griffiths, Oregon State Univ., Corvallis.

TABLE 4

Viable Counts of Lower Cook Inlet Sediment Samples

Station	Depth	CFU/g (x 10^6) ($\bar{\bar{X}}^1$, N = 5)	S.D.[2]
8	128	3.81	.38
5	150	3.41	.77
40A-1	33	6.84	.89
40A-2	33	17.87	4.55
28-1	31	25.14	3.01
27-1	33	7.89	1.67
27-2	33	36.76	5.15
62A-1	27	3.99	.98
62A-2	27	7.07	2.31
53	89	6.02	1.01
37	31	.92	.27
PMEL 7	85	3.28	1.72
PMEL 4	65	3.87	1.67

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[1] Arithmetic mean.
[2] Standard deviation.

TABLE 5

Carbon Content of Cook Inlet Sediment Samples

Sample	Wt (mg)	Total % C	Wt C (mg)	Total Wt C (mg) g^{-1} sediment	$\bar{X}^1$	Computed organic C mg g^{-1} sediment
Sta 5	4.227	.847	.0358	8.47	8.90	7.74
	3.965	.703	.0279	7.03		
	3.178	1.120	.0356	11.20		
Sta 8	2.411	.316	.0076	3.16	2.77	2.41
	2.851	.286	.0082	2.86		
	3.833	.230	.0088	2.30		
Sta 27	3.663	.884	.0324	8.84	9.97	8.67
	2.506	.887	.0222	8.87		
	3.931	1.220	.0479	12.20		
Sta 27	2.868	.426	.0122	4.26	4.70	4.28
	3.144	.576	.0180	5.76		
	3.956	.408	.0161	4.08		
Sta 28	3.933	.422	.0166	4.22	4.44	3.86
	3.972	.471	.0187	4.71		
	4.318	.440	.0190	4.40		
Sta 37	2.072	.880	.0182	8.80	9.15	7.96
	2.685	.907	.0244	9.07		
	2.476	.959	.0237	9.59		
Sta 37	2.867	.890	.0255	8.90	8.93	7.77
	2.581	.903	.0233	9.03		
	2.782	.888	.0247	8.88		
Sta 40A	4.186	1.450	.0607	14.50	16.70	14.53
	3.315	1.580	.0524	15.80		
	2.655	1.990	.0528	19.90		
Sta 40	3.916	.522	.0204	5.22	4.89	4.25
	2.878	.457	.0132	4.57		
	2.928	.489	.0143	4.89		
Sta 53	3.900	.670	.0260	6.70	6.02	5.24
	2.824	.553	.0150	5.53		
	3.047	.583	.0170	5.83		

TABLE 5

Continued

Sample	Wt (mg)	Total % C	Wt C (mg)	Total Wt C (mg) g^{-1} sediment	$\bar{X}$[1]	Computed organic C mg g^{-1} sediment
Sta 62A	3.803	.953	.936	9.53	13.40	11.66
	2.673	1.760	.047	17.60		
	3.653	1.320	.048	13.20		
Sta 62B	2.761	.549	.015	5.49	4.45	3.87
	3.150	.403	.013	4.03		
	2.722	.384	.010	3.84		
PMEL 1	3.898	.533	.021	5.33	6.83	5.94
	3.129	.946	.030	9.46		
	3.588	.571	.020	5.71		
PMEL 1	2.592	.737	.019	7.37	7.25	6.31
	2.431	.656	.016	6.56		
	2.475	.783	.019	7.83		
PMEL 4	3.315	.132	.004	1.32	1.53	1.33
	2.940	.246	.007	2.46		
	2.985	.082	.002	.82		
PMEL 4	2.128	.077	.001	.77	1.20	1.04
	2.791	.167	.005	1.67		
	2.741	.118	.003	1.18		
PMEL 7	3.464	.927	.032	9.27	9.05	7.87
	2.655	.893	.024	8.93		
	3.563	.897	.032	8.97		
PMEL 7	2.361	.377	.008	3.77	4.93	4.29
	1.993	.432	.009	4.32		
	2.547	.669	.017	6.69		
PMEL 7	2.360	1.250	.030	12.50	11.90	10.35
	1.997	1.180	.024	11.80		
	2.110	1.160	.024	11.60		
Sta 62A	2.412	1.090	.026	10.90	11.60	10.09
	3.460	1.500	.052	15.00		
	2.497	.885	.022	8.85		

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[1] Arithmetic mean.

Sediment bacterial carbon values were calculated and are included in Table 3. Computed carbon from bacterial sources ranged from 0.18 (Station 62A) to 6.2 (Station 37) mg g^{-1} sediment. Kachemak Bay area samples as a result of higher direct cell counts, had more bacterial carbon.

Figure 4 depicts the relationship of organic and bacterial carbon for selected stations in lower Cook Inlet. Estimated bacterial carbon constitutes from 2% (Station 40A) to nearly 80% (PMEL 7) of the organic carbon present in the sediments. On other stations (PMEL1, PMEL 4) bacterial carbon constituted approximately 50% of the organic carbon present in the sediment samples.

Respiration, Metabolic Rate

Data from respiration rate analysis are shown in Table 6. The average respiration rate of all *Crangon dalli* measured was 25.7 μl O_2 g^{-1} hr^{-1}, with a range of 9.3 μl O_2 g^{-1} hr^{-1} to 42.7 μl O_2 g^{-1} hr^{-1}. The data displayed rather high variability, S.D. = 10.2, and respiration rate was not well correlated with shrimp size ($r = .55$, $p > .02$). By use of the ideal gas law, the average volume of O_2 uptake (25.7 μl) can be converted to moles of O_2 (1.10×10^{-6}). Multiplication by a respiratory quotient of .8 gave a mole CO_2 evolution value of 8.81×10^{-7} moles CO_2 g^{-1} hr^{-1} (Table 7). Using the molecular weight of CO_2 and the fraction represented by carbon, carbon flux due to resting metabolism in the average *Crangon dalli* was calculated:

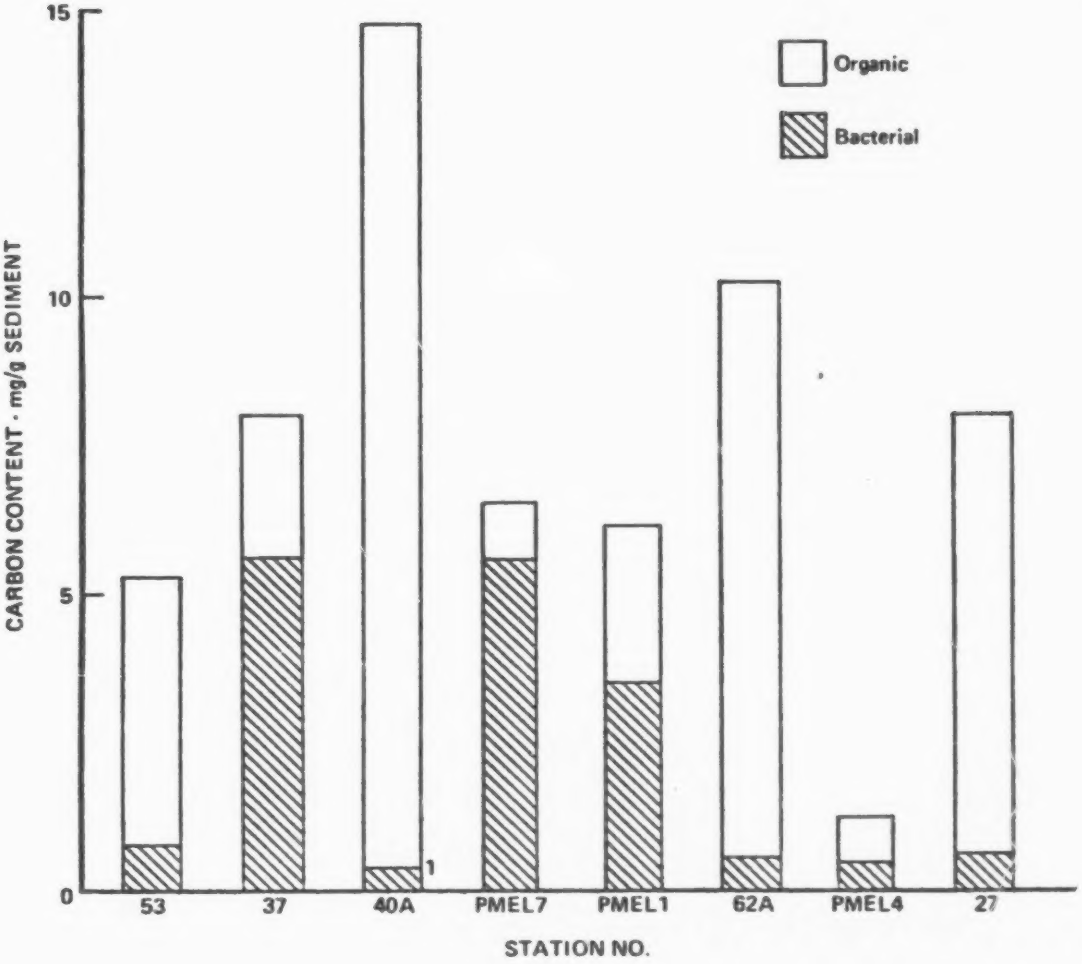

Figure 4. Relationship of bacterial and organic carbon values of sediment from selected stations in lower Cook Inlet. 1 denotes estimated from direct counts derived from viable counts.

TABLE 6

Respiration Rate of *Crangon dalli* at 4.5°C

Date	Individual shrimp wet Wt. (g)	No. readings		$\bar{X}^1$ uptake $\mu\ell$ O_2 g^{-1} hr^{-1}
3/16	1.84	4		22.8
	1.43	4		28.5
	1.70	4		22.9
3/19	1.44	4		27.0
	2.00	4		36.6
	1.70	4		42.7
	1.92	4		42.2
3/21	1.61	5		9.3
	2.13	5		20.3
4/3	2.60	3		19.8
4/5	2.10	6		9.4
	1.80	6		16.0
	2.55	6		19.0
4/6	2.03	4		32.8
	2.15	4		30.1
	3.04	4		39.7
4/16	1.50	5		23.2
			mean	25.7
			S.D.	10.2

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[1] Arithmetic mean.
[2] Standard deviation.

TABLE 7

Oxygen Consumption and Carbon Dioxide Evolution of *Crangon dalli* at 4.5°C

Exp. Date	Pressure (atm)	moles O_2 uptake g^{-1} hr^{-1}	moles CO_2 evolved g^{-1} hr^{-1}
3/16	.970	9.60×10^{-7}	7.75×10^{-7}
		1.21×10^{-6}	9.70×10^{-7}
		9.74×10^{-7}	7.79×10^{-7}
3/19	.977	1.15×10^{-6}	9.25×10^{-7}
		1.56×10^{-6}	1.25×10^{-6}
		1.82×10^{-6}	1.46×10^{-6}
		1.81×10^{-6}	1.45×10^{-6}
3/21	.980	4.00×10^{-7}	3.19×10^{-7}
		8.7×10^{-7}	6.98×10^{-7}
4/3	.975	8.47×10^{-7}	6.77×10^{-7}
4/5	.971	4.00×10^{-7}	3.20×10^{-7}
		6.81×10^{-7}	5.45×10^{-7}
		8.09×10^{-7}	6.47×10^{-7}
4/6	.964	1.39×10^{-6}	1.11×10^{-6}
		1.27×10^{-6}	1.01×10^{-6}
		1.68×10^{-6}	1.34×10^{-6}
4/16	.984	1.00×10^{-6}	$.80 \times 10^{-6}$

Sample calculation: $Pv = nRT$; P = pressure in atmospheres the day of the experiment
R = .0821 liter atm/°K mole
T = 277.5°K
v = volume O_2 uptake
n = number moles O_2

$$\frac{(.974)(2.57 \times 10^{5} \text{ liter})}{(.0821 \text{ liter atm/°K mole})(277.5\text{°K})} = 1.10 \times 10^{-6} \text{ moles}$$

Respiratory Quotient of .8: $(1.10 \times 10^{-6})(.8) = 8.81 \times 10^{-7}$ moles CO_2

$(8.81 \times 10^{-7}$ moles CO_2 g^{-1} hr^{-1} $(44$ g CO_2 $mole^{-1}) =$

3.88×10^{-5} g CO_2 g^{-1} hr^{-1}

or 1.05×10^{-5} g C g^{-1} hr^{-1}.

DISCUSSION

Virtually all of the prey categories and the gut contents observed have their origin on the bottom. Exceptions such as diatoms, chaetognaths, and fish remains are best explained as dead organic matter (detritus) which has its origin in the water column and has settled to the bottom. In some areas of lower Cook Inlet (Kachemak Bay) up to 12% of primary production in the water column fluxes rapidly to the benthos (Larrance, 1979). Fish remains in crangonid gut contents clearly are a result of dead animals being ingested on the bottom. The large number of food categories (60) is a reflection of the feeding style of these animals. However, it is noteworthy that some of the categories observed in this report may be of limited value as food. A number of polychaete occurrences listed in Table 1 were based on setae identification, not on whole worms. Setae themselves would be of limited food value. Identification of diatom tests in gut contents may bias frequency of occurrence information in that their value as food is questionable. Results of the present study of Cook Inlet crangonids indicate they are clearly generalists employing an opportunistic strategy, that is, eating whatever is available. Similar findings with regard to prey and habits were noted by Wilcox (1974) for an east coast crangonid. From the results of a study of *Crangon septemspinosa*, he concluded they fed on the bottom and would eat virtually anything. He noted that variation in gut contents may arise from availability of foods, not necessarily preference. That author considers *C. septemspinosa* an omnivore and agrees with an earlier classification (Price, 1962) of the animal as a secondary consumer. It is significant that through direct consumption and as a predator on other detrital feeding organisms (i.e., secondary consumer) Cook Inlet crangonids are dependent on the sediment-detrital food system for their energetic needs.

The observed high frequency of sediment ingestion in the present report is consistent with the study of Wilcox (1974). However, sand was considered to constitute only 4% of the total volume of *Crangon septemspinosa* contents. In Cook Inlet crangonids, inorganic sediment (which includes sand) constituted an overall average of 55.75% (dry weight basis) of the stomach contents after KOH digestion of organic matter. A high percentage contents of sediment in Cook Inlet pandalid shrimps and hermit crabs has been similarly noted (Rice *et al.*, 1980; Feder *et al.*, 1980). Although volumetric estimations were not done in the present study, sediment constitutes a larger fraction of the contents of Cook Inlet crangonids than that found in *C. septemspinosa*. The percent dry weight sediment component was consistently high with two exceptions noted above. These two values may reflect experimental error in that their determination was the first done in the laboratory. It is again noteworthy that the method employed for estimating sediment in this report can be expected to underestimate the actual amount present.

However, this is probably less than volumetric analytical error, considering the rather small size of the animals and their stomachs.

Microbial biomass estimates of Cook Inlet sediments in the present study are in agreement with other recent studies. Atlas (1979) report 6.4×10^8 cells ml^{-1} from direct counts of sediment samples in inner Kachemak Bay. In Kamishak Bay 3.7×10^8 cells ml^{-1} were observed. Viable counts of these sediments ranged from 4.4×10^6 to 1.8×10^6 CFU g^{-1} units respectively. Viable counts are typically less than direct counts because direct counts include non-viable cells and some bacteria present in the sample may be unable to grow on the media used for the viable count analysis. Griffiths and Morita (1979) report that microbial activities of Cook Inlet sediments were highest in the Kamishak and Kachemak Bay areas. Microbial activity values from 58 ng glutamate g^{-1} hr^{-1} (Kamishak Bay) to 380 ng glutamate g^{-1} hr^{-1} (inner Kachemak Bay) were reported in that study.

Total carbon values of Cook Inlet samples are likely reliable and realistic. However, calculation of organic carbon from total carbon by the method employed increases the potential for error. The organic carbon value for Station 62A was high ($\sim$ 10 mg g^{-1} sediment) while the microbial carbon value was extremely low ($<$ 1 mg g^{-1} sediment). It is noteworthy that large amounts of clam shells ($CaCO_3$) and significant fresh water runoff are found in this area, potentially influencing the inorganic carbon fraction relative to other stations. The presence of such carbon sources on some stations (62A) may in part explain the large difference (relative to other stations such as PMEL 7) between bacterial carbon values and organic carbon values. Yet, in general, as a means of relative comparison between stations the method is probably acceptable. The contribution of bacterial carbon is potentially significant from a nutritive standpoint. Certain forms of detrital carbon are thought to be of limited value to organisms due to their refractory quality or high C:N ratio.

Respiration rates of *Crangon dalli* in this study were somewhat lower than other crangonids and crustaceans. Hagerman (1970) reported oxygen consumption rate of *Crangon vulgaris* at 6°C to range from 100-200 μl O_2 g^{-1} hr^{-1}, depending on size and salinity. The crab, *Uca* (weight 2 g) at 12°C showed oxygen uptake of 45 μl g^{-1} hr^{-1} (Lockwood, 1967). The average resting rate of *C. dalli* in the present report may be somewhat high due to the influence of the method on the animal's behavior. It is possible that the rate observed here may approach that of active or feeding levels. The carbon flux figure, 1.05×10^{-5} g C g^{-1} hr^{-1} calculated from respiration rates above, can be used to compute carbon demand per day for the average adult shrimp. Thus, a 2 g adult *Crangon dalli* at 4.5°C would need .5 mg carbon in a 24-hour period.

The relationship of the caloric value of ingested sediment with the metabolic needs of the animal is interesting. Additionally, sediment-detrital quality and feeding habits are potentially a function of the oceanographic conditions found at the various stations. Table 8 summarizes the various parameters in this context. For these calculations it was assumed two gut loads were processed daily. Wilcox (1974) reported

TABLE 8

Relationship of Oceanographic Conditions with Sediment Quality and Maximum Sediment Contribution to the Energy Budget of *Crangon* sp.

Station	$g\ m^{-2}$ *Crangon*	Oceanographic conditions and rate carbon delivered to bottom	Sediment organic C (mg C g^{-1} sediment)	Bacterial carbon (mg C g^{-1} sediment)	$\bar{X}$ amount sediment in gut contents (g)	Daily % Energy[1] Available to *Crangon*[2]	
						Total organic	Bacterial only
PMEL 7	.012	gyre system, productive waters; sediment rich, 60 g C m^{-2} (4-month period)	4.29-10.35	4.8 -5.8	.0025	4.3%-10.4%	4.8%-5.8%
40A	.008		14.53	.001 -1.23[3]	.001	5.8%	<.5%
37	.18		7.77-7.96	5.1 -6.2	na	-	-
PMEL 1	.022	smaller gyre system suggested, sediments fine, some glacially derived; 40 g C m^{-2} (4-month period)	5.94-6.31	2.47 -4.4	.003	7.1%- 7.6%	3.0%-5.3%
62A	.05		10.09-11.66	.18 - .53	.004	16.1%-18.6%	.3%- .8%
PMEL 4	.009	no evidence of gyre, strong currents, course sediments; 17 g C m^{-2} (4-month period)	1.04-1.53	.0003-.3[4]	na	-	-
53	.014		5.24 -	.5	.007	14.8%	1.4%
Maximum potential - highest values from all categories			14.53	6.2	.007	40.1%	17.4%

---

[1] Average daily need based on calculated value of .5 mg C/24 hours

[2] Process two average gut loads per day

[3] Based on viable counts (.001), estimate 1.23 if computed from probable number of direct counts

[4] Based on viable counts (.003), estimate 0.3 if computed from probable number of direct counts

a gut transit time of 6-12 hr in *Crangon septemspinosa*. Hence, the average amount of sediment in the gut contents was doubled in the computation. Two general relationships are noted.

(1) There is a relationship of sediment organic and bacterial carbon values with oceanographic conditions and sedimentation rates. The effect of productive waters, gyre systems, and rapid delivery of carbon to the bottom (PMEL 7, 40A, 37) is reflected in higher carbon values in the sediments. Stations PMEL 4 and 53 are in extreme contrast showing impoverished sediments, with Stations PMEL 1 and 62A somewhat in the middle of the two groups of stations.

(2) Lower carbon values appear to result in more sediment consumption by *Crangon*. Stations where sediments were richest (40A, PMEL 7) showed the lowest average amount of sediment in the gut contents. On stations with poorer sediments (e.g., 53) *Crangon* is observed to ingest more sediment. Although these relationships are not totally clear cut, the general trend is evident, and would be clarified with further sampling.

With respect to energy potentials on stations examined, total sediment organic carbon may represent from 4.3% (Station PMEL 7) to 18.6% (Station 62A) of the animal's daily metabolic needs. Further, the bacterial fraction alone could constitute from .5% (40A) to 5.3% (PMEL 1) of the energetic requirements. Bacterial carbon constitutes a small fraction of the sediment organic carbon pool on some stations (40A) and a significant portion of that pool on others (PMEL 1, 7). For example, on Station PMEL 7, bacteria constitute nearly 50% of the organic pool, while nearby on Station 40A bacterial carbon is a negligible fraction of the organic pool. A hypothetical maximum potential was calculated using the highest values from all categories. In this instance, total sediment organic carbon could represent as much as 40% of the animals daily needs with 17% of that coming from bacterial sources.

Observed percent energy potentials from sediment sources represent a sizeable contribution to the energy budget of *Crangon*. However, it is noteworthy that these contributions in themselves are insufficient for growth and reproduction. Thus, these estimates are consistent with the opportunistic scavenging and predatory behavior observed in Cook Inlet crangonids.

Due to the limited data, no discussion of seasonal effects or nitrogen content of sediments is included. However these two parameters are potentially important. Seasonal production may well affect the quality of food and sediment available to detrital feeding animals in the benthic community. The carbon/nitrogen ratios of potential food sources is an important factor in determining ingestion rates.

Summary and Conclusions

The nature of crangonid feeding habits is interesting and suggests a unique adaptation. Feeding behavior and the amount of sediment ingestion are related to the dynamics of the system. Prey avialability and food resources in the nearshore benthos are quite variable. Shrimp will ingest whatever prey is available in large amounts. Under impoverished conditions accidental or deliberate ingestion of sediment and the apparent ability to utilize affiliated carbon sources enhances their nutritive intake. A low metabolic rate and sedentary habits serves to reduce caloric needs. Their feeding habits indicate that if hydrocarbons were to become associated with sediments, they would be ingested by *Crangon*. Topics worthy of consideration for future research include examination of sediment organic carbon quality and resuspension of bottom sediments.

REFERENCES

Adams, S. M. and J. W. Angelovic. 1970. Assimilation of detritus and its associated bacteria by three species of estuarine animals. *Chesapeake Science*, Vol. II, No. 4, pp. 249-254.

Atlas, R. M. 1979. Assessment of potential interactions of microorganisms and pollutants resulting from petroleum development on the outer continental shelf of Alaska. Annual Rept. to OCSEAP, R.V. #29. NOAA, Bolder, Colorado.

Baker, J. H. and L. A. Bradnam. 1976. The role of bacteria in the nutrition of aquatic detritivores. *Oecologia* 24:95-104.

Burbank, D. C. 1974. Suspended sediment transport and deposition in Alaskan coastal waters. Master's Thesis, Univ. Alaska, Fairbanks.

Burbank, D. C. 1977. Circulation studies of Kachemak Bay and Lower Cook Inlet. *In* L. L. Trasky, L. B. Flagg and D. C. Burbank (eds.), *Environmental Studies of Kachemak Bay and Lower Cook Inlet*, Vol. III. Alaska Dept. Fish and Game, Anchorage.

Crow, J. H. 1977. Food habits of shrimp in Kachemak Bay, Alaska. *In* L. L. Trasky, L. B. Flagg and D. C. Burbank (eds.), *Environmental Studies of Kachemak Bay and Lower Cook Inlet, Alaska*, Vol. VI. Alaska Dept. Fish and Game, Anchorage.

Feder, H. M., A. J. Paul, M. Hoberg, S. Jewett, G. Matheke, K. McCumby, J. McDonald, R. Rice and P. Shoemaker. 1980. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of Cook Inlet. Annual Rept. to OCSEAP, R.V. #5. Inst. Mar. Sci., Univ. Alaska, Fairbanks.

Fenchel, T. M. and B. Jørgensen. 1977. Detritus food chains of aquatic ecosystems: The role of bacteria. *In* M. Alexander (ed.), *Advances in Microbial Ecology*, Vol. 1. Plenum Press, New York. pp. 1-58.

Griffiths, R. P. and R. Y. Morita. 1979. Study of microbial activity and crude oil-microbial interactions in the waters and sediments of Cook Inlet and the Beaufort Sea. Annual Rept. to OCSEAP, R.U. #190. NOAA, Boulder, Colorado.

Kofoed, L. H. 1975. The feeding biology of *Hydrobia ventrosa* (Montagu) II. Allocation of the components of the carbon-budget and the significance of the secretion of dissolved organic material. *J. Exp. Mar. Biol. Ecol.* 19:243-256.

Hagerman, L. 1970. The oxygen consumption of *Crangon vulgaris* (Fabricus) (Crustacea, Natantias) in relation to salinity. *Ophelia* 7:283-292.

Holme, N. A. and A. D. McIntyre (eds.). 1971. *Methods for the Study of Marine Benthos*. Publications for the International Biological Program. Oxford Backewell Scientific Publications, London. 334 pp.

Larrance, J. D. and C. Alexander. 1979. Source composition and flux of organic detritus in Lower Cook Inlet. Final Rept. to OCSEAP, R.U. #425. NOAA, Boulder, Colorado.

Lockwood, A. P. 1967. *Aspects of the Physiology of Crustacea*. University Reviews in Biology. W. H. Freeman and Co., San Francisco. 328 pp.

Mann, K. H. 1972. Macrophyte production and detritus food chains in coastal waters. *Mem. Ist. Idrobiol*. Suppl. 29:353-383.

Paul, A. J., H. M. Feder and S. J. Jewett. 1979. Food of the snow crab *Chionoecetes bairdi* Rathburn, 1924, from Cook Inlet, Alaska (Decapoda, Majidae). *Crustaceana* Suppl. 5:62-68.

Price, K. S., Jr. 1962. Biology of the sand shrimp *Crangon septemspinosa* in the shore zone of the Delaware Bay region. *Cheasapeake Science* 3:244-255.

Rathburn, M. J., H. Richardson, S. J. Holmes and L. J. Cole. 1910. *Crustacea*. Alaska Vol. X, Harriman Alaska Expedition. Doubleday, Page and Co., New York.

Rice, R. L., K. McCumby and H. M. Feder. 1980. Food of *Pandalus borealis*, *Pandalus hypsinotus* and *Pandalus goniurus* (Pandalidae, Decapoda) from Lower Cook Inlet, Alaska. Proceedings National Shellfisheries Assn., Vol. 70. In press.

Rieper, M. 1978. Bacteria as food for marine harpacticoid copepods. *Marine Biology* 45:337-345.

Sharma, G. D. and D. C. Burrell. 1970. Sedimentary environment and sediments of Cook Inlet, Alaska. *Amer. Assoc. Petroleum Geol. Bull.* 54(4):647-654.

Tenore, K. R. 1975. Detrital utilization by the polychaete, *Capitella capitata*. *J. Marine Research* Vol. 33, 3:261-274.

Tenore, K. R. 1977. Food chain pathways in detrital feeding benthic communities: A review, with new observations on sediment resuspension and detrital recycling. *In* B. C. Coull (ed.), *Ecology of Marine Benthos*, USC Press. pp. 37-53.

Umbreit, R. H., R. H. Burris and J. F. Stauffer. 1964. *Manometric Techniques*. Burgess Publishing Co., Minneapolis 15, Minn.

Wetzel, R. G., P. H. Rich, M. C. Miller and H. L. Allen. 1972. Metabolism of dissolved and particulate detrital carbon in a temperate hard-water lake. *Mem. Ist. Ital. Idrobiol.* Suppl. 29:185.

Zimmerman, R. and L. Meyer-Riel. 1974. A new method for fluorescence staining of bacterial populations on membrane filters. *Kiel. Meeresforsch* 30:24-27.

APPENDIX

ASSIMILATION OF BACTERIAL CARBON BY CRANGONID SHRIMP

PREFACE

Attempts to measure assimilation of bacterial carbon by crangonid shrimp are described in the following section. A great deal of interest is currently centered on this topic. Many investigators have attempted to measure assimilation of carbon from bacteria by using radiolabeled bacteria (Adams and Angelovic, 1970; Kofoed, 1975; Rieper, 1978). Although methodological problems exist with this approach, most authors agree that the radiolabeling approach has the necessary sensitivity and is experimentally feasible.

In the experiments described here, the primary goal was to see if crangonid shrimp could digest bacteria and assimilate released carbon by ingesting sediment or detritus enriched with 14-C labeled bacteria. A secondary goal was, if possible, to determine amounts and rates of assimilation. This second interest was important if the significance of bacterial carbon in the diet of these shrimps was to be addressed. However, this second goal complicated the methodology; it was more difficult to determine rates than simply to look for the appearance of label in the body tissue of the shrimps.

Such investigations can prove time consuming, expensive, and experimentally difficult. Constraints on this research existed due to the format under which it was to be conducted.. Yet, the question was interesting and was of value both for its intrinsic worth as well as an educational experience for this author.

INTRODUCTION

The use of radioisotopes in studies of detrital food systems has grown both in usage and in sophistication. Detrital utilization studies (Tenore, 1975, 1977), carbon budget studies (Kofoed, 1975), assimilation studies (Adams and Angelovic, 1970; Cummins, 1973), and bacterial assimilation studies (Rieper, 1978) are but a few reports in the literature which reflect the growing use of radioisotopes and their applications in investigations dealing with detrital food systems. Although they are not equally useful in all systems (Conover and Francis, 1973), radioisotopes possess the necessary sensitivity and experimental flexibility to be a powerful research tool. In recent years, advances in areas such as liquid scintillation counting, and increased availability of a wide variety of radioisotopes has made the use of isotopes even more attractive.

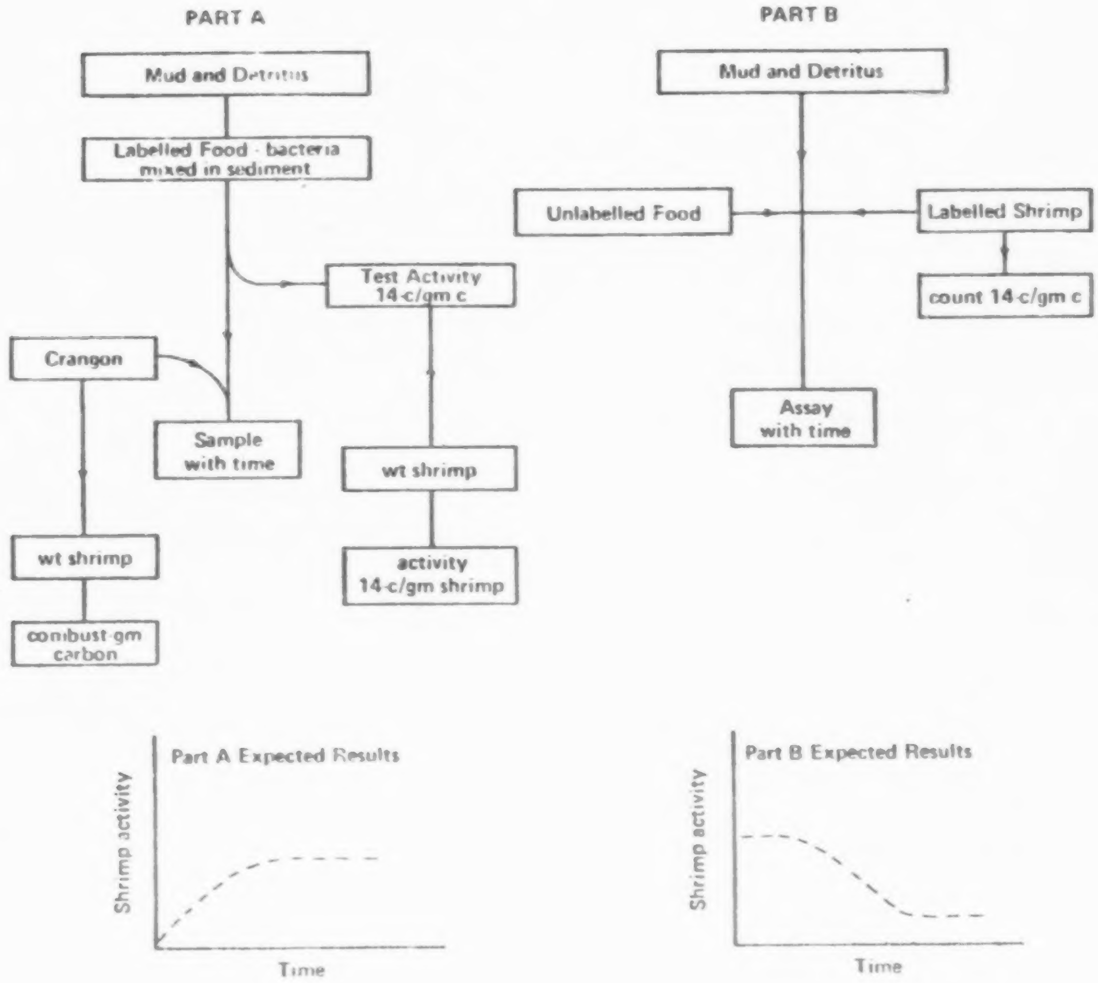
The potential of bacterial carbon as energy source for crangonid shrimp in lower Cook Inlet, Alaska has been alluded to in this report. Yet the significance of this carbon source can not be estimated without evidence that these shrimp are in fact able to digest bacteria and assimilate released carbon compounds. Other investigators have shown that related shrimp can survive, and indeed grow on a diet of bacteria (Wilcox, 1974). Certain prawns (*Metapenaeus*) are believed to utilize bacteria as a food source in their natural diet (Moriarty, 1978). However, there were no studies on Alaskan crangonids nor were there any estimates of assimilation efficiency or rates of uptake of carbon derived from bacteria. Further, there may be a difference between rates of assimilation of bacterial carbon from a "sediment-detrital" slurry source, and from massive amounts of bacteria spun into a pellet and fed directly to shrimp. Hence the goals in the current investigation were on two levels: (1) to answer the very basic question of simply whether or not Alaskan crangonids could assimilate bacterial carbon and (2) providing the answer to 1 was affirmative to determine the rate and efficiency of assimilation.

Appendix Figure 1 depicts the overall experimental approach as originally conceived and presented in my proposal for graduate research outline. The two phases of the work were intended to enable me to calculate carbon uptake rate for the shrimp. Thus, the work as outlined, if successful would answer both of the questions posed above. However, after further consultation with Dr. D. Holleman and Dr. M. J. Klug, modifications to the procedure were incorporated in an attempt to simplify the approach. The opinion was that the experiments as proposed would be much too difficult and complicated and time consuming to be carried out under the existing format.

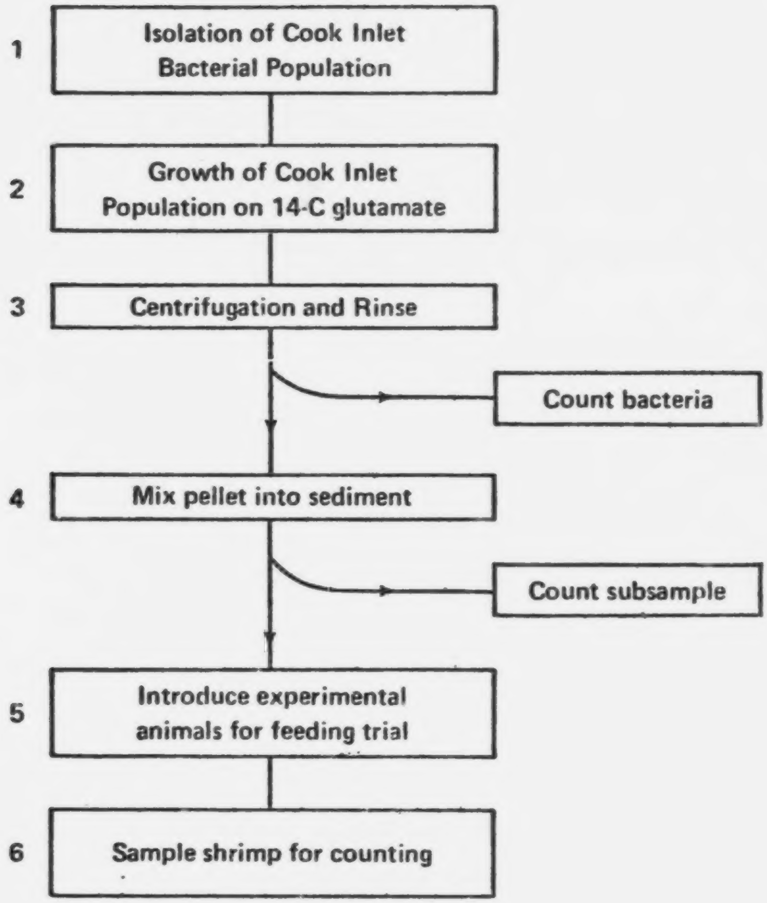
METHODS

Labeled Bacteria Approach

Appendix Figure 2 depicts a flow diagram of the first experimental method employed in this investigation. In the interest of simplicity and in an attempt to obtain an answer to the more basic question of


PART A
Mud and Detritus
Labelled Food - bacteria mixed in sediment
Test Activity 14-c/gm c
Crangon
Sample with time
wt shrimp
activity 14-c/gm shrimp
wt shrimp
combust-gm carbon
PART B
Mud and Detritus
Unlabelled Food
Labelled Shrimp
count 14-c/gm c
Assay with time
Part A Expected Results
Shrimp activity
Time
Part B Expected Results
Shrimp activity
Time

Appendix Figure 1. Original conception of radioisotope experiments. In part A the animals are on a radioactive food source. In part B radioactive animals are on an unlabeled food source. The graphs under expected results merely indicate the general trend expected. The purpose of the loading and unloading experiments was to be able to calculate carbon uptake rate by difference.

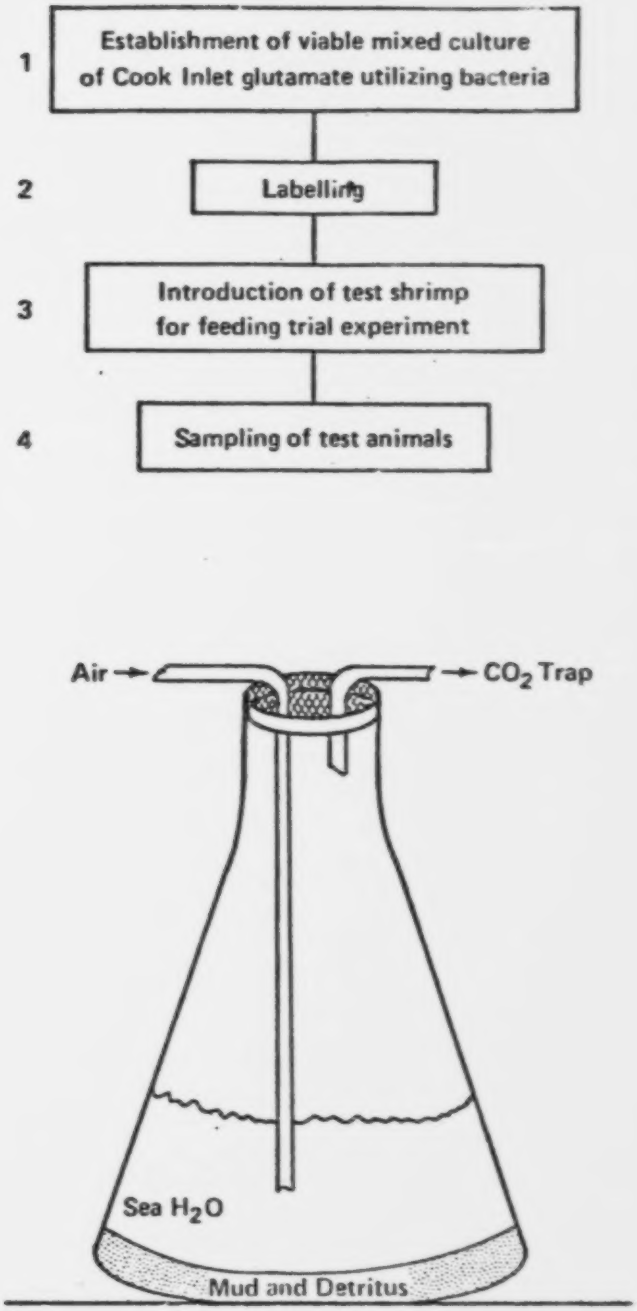

1
Isolation of Cook Inlet Bacterial Population
2
Growth of Cook Inlet Population on 14-C glutamate
3
Centrifugation and Rinse
Count bacteria
4
Mix pellet into sediment
Count subsample
5
Introduce experimental animals for feeding trial
6
Sample shrimp for counting

Appendix Figure 2. Previously cultured labeled bacteria approach.

bacterial carbon assimilation, the loss of label portion of Appendix Figure 1 was eliminated and a simple "loading" experiment was performed. This method consisted of 6 steps. In Step 1, a mixed culture of Cook Inlet bacteria was established by enrichment on a glutamate containing media. In this way, uptake of radiolabeled glutamate would be facilitated (Step 2). After centrifugation and rinsing (Step 3) bacteria was counted, and the pellet was mixed into a sediment detrital slurry to uniformity (Step 4). A subsample of this final mixture was also counted for 14-C activity. Step 5, then, was the introduction of the experimental animals, usually shrimp, although the technique was applied in the first run to *Macoma* clams. Step 6 was the sampling and counting of the experimental animals.

Closed Mini-Ecosystem Approach

Appendix Figure 3 depicts the methodology used in a second series of experiments. In this system a more dynamic approach is used, where a mini-ecosystem is set up and growth of bacteria and feeding trials of the shrimp are both carried out in a closed system. At the outset, it was felt that if this system worked properly, it would be easily expanded so that label unloading of tissues could be observed, hence, computation of rate of assimilation and turnover would be facilitated. Further, this system was believed to better approximate the natural environment where the shrimp are found. Bacteria should be attached and viable if this method is correct, and shrimp would then be required to digest them off the sediment and then void the sediment.


1
Establishment of viable mixed culture of Cook Inlet glutamate utilizing bacteria
2
Labelling
3
Introduction of test shrimp for feeding trial experiment
4
Sampling of test animals
Air
CO2 Trap
Sea H2O
Mud and Detritus

Appendix Figure 3. Experimental set up for closed mini-ecosystem approach. The test chamber is a specially modified 6 L Ehrlenmeyer flask.

BEST DOCUMENT AVAILABLE

Four principal steps were involved in this method. First, a culture of Cook Inlet glutamate utilizing bacteria was established in a large airtight flask (Step 1). Sediment was enriched with amino acids to prompt growth of potential glutamate users. Then, in Step 2, 14-C labeled glutamate was introduced. At this time the system was sealed and evolved gases from the chamber were passed through a CO_2 trap. The solution in the trap was monitored and counted so that uptake and respiration of the label by the bacteria could be detected (see sample preparation, below). After it was determined that the bacteria population was actively growing, incorporating and respiring label, the test animals were introduced for the feeding trial (Step 3). A sufficient number of shrimp were used to allow for non-feeding individuals and individual variation. The final step then was the sampling and counting of the animals with time (Step 4) (see sample preparation).

Preparation of Standards, Samples, and Scintillation Information

Appendix Table 1 summarizes information concerning the scintillation cocktails and methods used for the various types of samples. A series of quenched standards for each type of sample were prepared and counted. It was found that quenching of the various samples differed significantly (i.e., slopes of counting efficiency versus external standards ratio differed), thus making it necessary to prepare such a series for each type of sample. These standards could then be used in the analysis of samples from the experiments.

APPENDIX TABLE 1

Sample Preparation and Liquid Scintillation Information

Type of Sample	Amount Sampled	Ingredients of Cocktail and Treatment
Tissue homogenates	1/4 homog-.8 ml	2.0 ml protosol; digest at 50°C overnight; .1 ml H_2O_2, 15 ml LSC[1]; Efficiency range 50-80%; Slope of quench curve 10.6.
CO_2	-	2.0 ml protosol; 8 ml LSC, 8 ml methanol; Efficiency range 40-70%; Slope of quench curve 11.8.
Seawater	1 ml	15 ml Aquasol; Efficiency range 80-90%; Slope of quench curve 2.96.
Sediment	1. - .5 ml	Same as tissue homogenates; Efficiency range 50-80%; Slope of quench curve 10.2.

LSC information: Bechman LS 100C counter with external standards ratio capability - count time, 10 min. each.

[1] LSC = Omnifluor/toluene; 4 g/liter
Quench curve = counting efficiency (cpm/dpm) versus external standards ratio (ESR)
Omnifluor, Protosol available from New England Nuclear,
label was L-Glutanic Acid [^{14}C(U)] - New England Nuclear. Lot 1152-038
Specific activity 296 mCi/m mole.

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Samples for counting were collected in the following manner. Shrimp were killed, rinsed, and the tail section removed. The shell was removed and the tissue again rinsed. The intestine, lying along the ventral surface of the tail section was carefully dissected out and the tail tissue again rinsed. The tissue was then weighed and a 1:4 homogenate was prepared in a Waring blender fitted with a micro-cup. A .8 ml subsample was then removed for the protosol treatment and counting. In some cases, the intestines and gills of the animal were also counted. Clams were killed, rinsed, and the gut, intestine, and gills removed. The remaining tissue was again rinsed, removed from the shell, weighed and used to prepare a 1:4 homogenate as above. A control animal was also in the test chamber in a cloth-mesh enclosed vial so that it would not be able to feed.

Sediment samples were siphoned off the surface of the substrate with a pipette and placed directly in a scintillation vial and treated with Protosol, as were the tissue homogenates. Incubation of sediment and tissue samples at 50°C with Protosol greatly facilitates solubilization. After the samples are digested, bleaching with peroxide helps in the reduction of color quenching.

Seawater samples of 1 ml were taken from the experimental chambers using a pipette and counted in Aquasol. One such sample was taken, counted, then acidified (.1 N HCL) and recounted. It appeared that most of the activity (∿ 90%) in the water was in the form of bicarbonate.

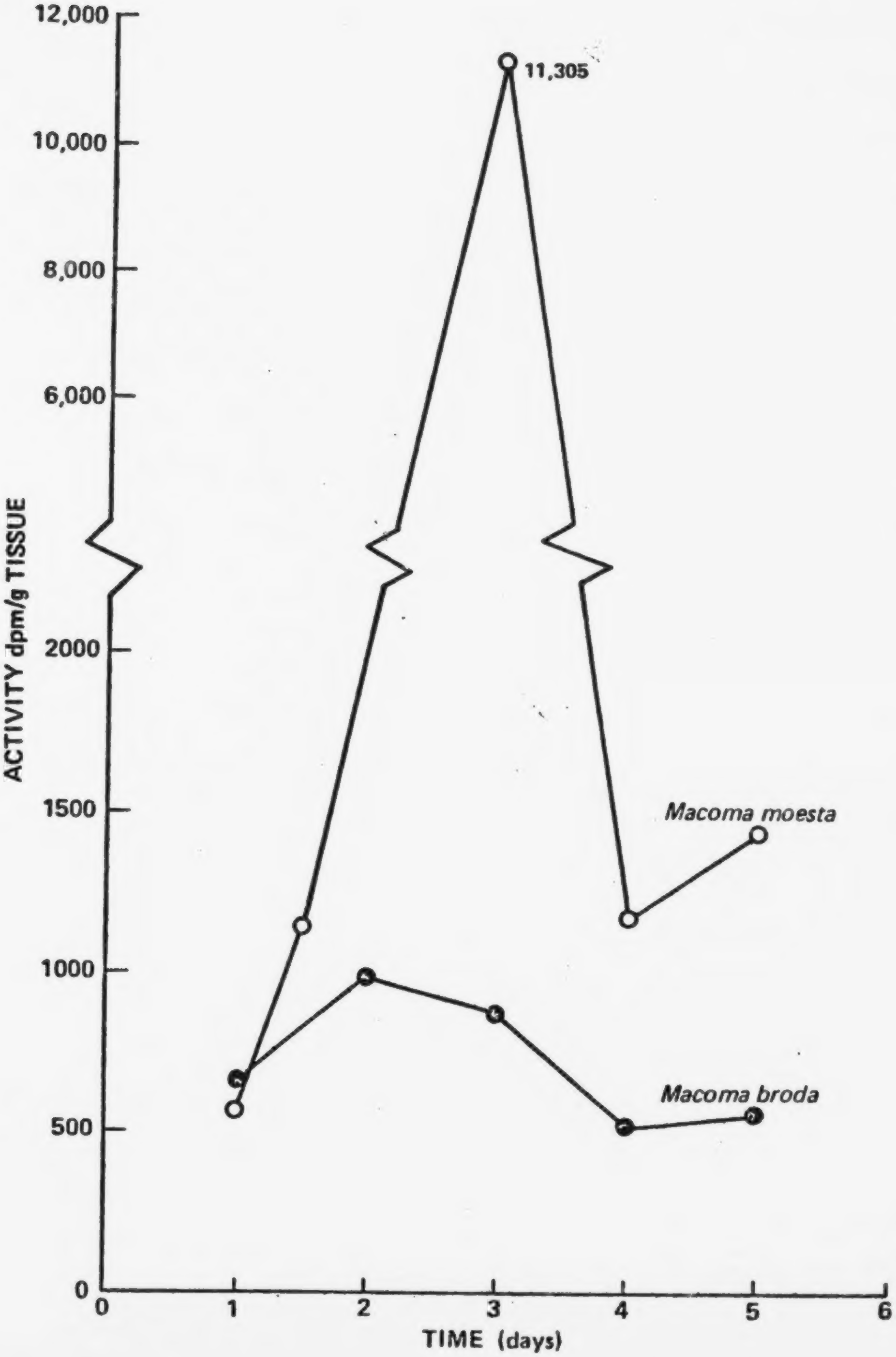
CO_2 samples were taken from a manifold of scintillation vials which contained the cocktail described in Appendix Table 1. Specially prepared caps for the vials were drilled, fitted with glass tubing, and then sealed with silicone so that air and gases from the experimental chamber (air-tight) would pass through the manifold and CO_2 trapping cocktails. The vials were connected in series so that the evolved gases would pass through a total of six vials before going through a final trap. It was determined that more than 90% of the counts evolved were trapped in the first vial, and that the last or sixth vial in the manifold trap set-up showed only background levels of activity.

RESULTS

Previously Cultured Labeled Bacteria Experiments

Appendix Figure 4 displays the results of the first experiments in which clams of the genus *Macoma* were allowed to feed on a sediment-detrital mixture containing bacteria which had been previously grown on a medium containing 14-C glutamate. As evidenced by the graph, clam tissue showed a maximum of activity 2-3 days after the experiment began. The general shape of the curves for the two species of clams was similar, although the actual amounts of activity differed somewhat. The activity observed in the clam tissue homogenates was low relative to the bacterial culture broth, which when counted showed 2×10^6 dpm ml^{-1}. However, the final sediment-detrital mixture showed 7×10^3 dpm ml^{-1} when the test animals were introduced.

The experiment using culture grown labeled bacteria as food for crangonid and pandalid shrimp proved to be unsuccessful. Although



Appendix Figure 4. Activity of clam tissue homogenates.

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labeled bacteria were successfully grown, the test animals did not feed, and some died. The experiment was carried to completion anyway. It is of interest that non-feeding animals typically showed low activities throughout the experiment, with tissue activities as well as activity of the water staying near background levels. The sediment-detrital mixture was found to have an activity of 5.8×10^4 dpm ml^{-1}.

Closed Mini-Ecosystem Experiments

Results of the first attempts at the closed system assimilation experiment are summarized in Appendix Tables 2 through 4. It is evident from Appendix Table 2, $^{14}CO_2$ evolution, that the bacteria readily incorporated the 14-C glutamate label. Further, after mixing the bacterial growth mixture into the sediment-detrital mixture, the final substrate upon which shrimp were placed for the feeding trial, showed high levels of activity (3.5×10^4 dpm ml^{-1}). The sediment activity varied with time as indicated in Appendix Table 3.

Activity data for individual shrimp homogenates are graphed in Appendix Figure 5. Activity appeared rapidly in shrimp tail tissue and then tapered off to lower levels by the end of the experimental period. Gills of these same shrimp showed very high activity levels (to 42000 dpm). These animals were observed to feed during the experiment. Appendix Table 4 displays an account of the label for the experiment.

A second experiment, utilizing the same approach as the one above, but with more animals was attempted. Again bacteria incorporated label (7×10^5 dpm in 24 hr) and the substrate for the feeding trial showed

APPENDIX TABLE 2

$^{14}CO_2$ Evolution from Bacterial Growth

Experimental Time (hrs)	DPM/6 vials (CO_2 trap)
6.75	6.43×10^5
15	2.43×10^6
18.5	3.55×10^6
26.5	4.32×10^6
Bacterial growth-total $^{14}CO_2$ evolved	
$^{14}CO_2$ evolved during feeding trial	$\underline{1.43 \times 10^6}$
Total CO_2	

APPENDIX TABLE 3

Activity of Sediment Samples During Feeding Trial

Experimental Time (hr)	Activity (dpm ml^{-1})
T = 0	3.50×10^4
4.25	9.88×10^4
12.50	1.34×10^5
15.75	4.98×10^4
20.00	7.08×10^4
25.00	1.75×10^5
29.00	1.13×10^5
38.00	2.96×10^4

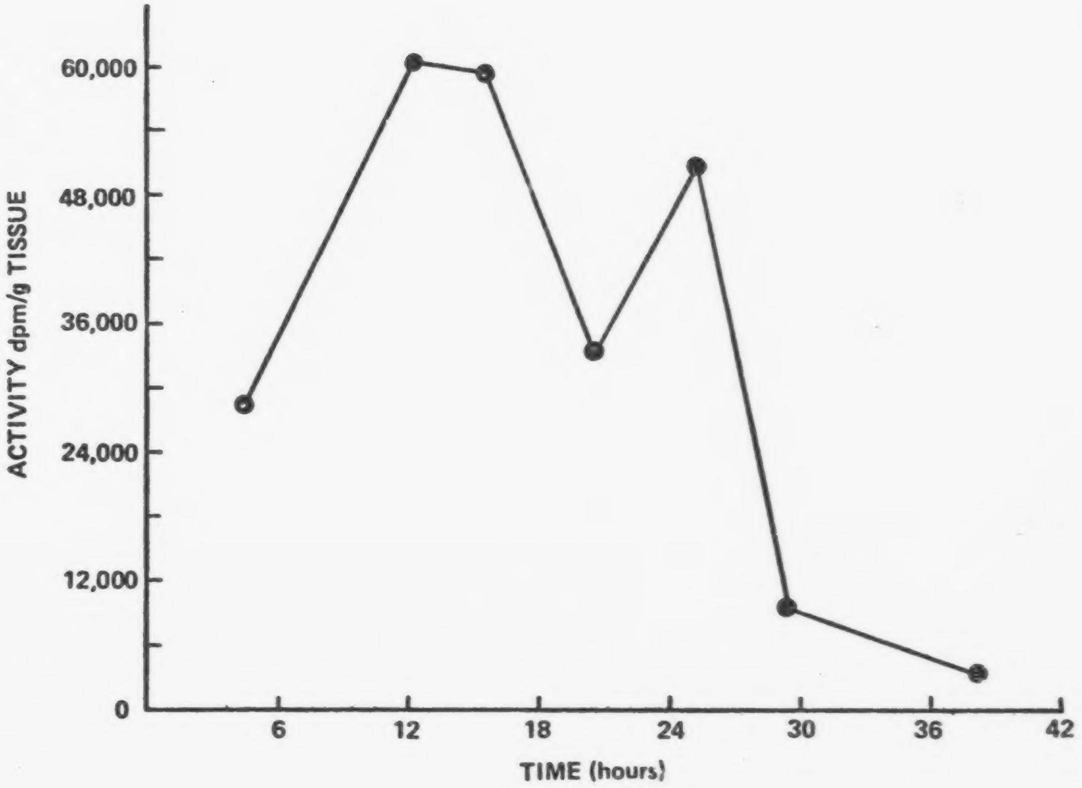
APPENDIX TABLE 4

14-C Label Account for Mini-Ecosystem Bacterial Growth and Shrimp Feeding Trial

Introduce 20×10^7 dpm

CO_2 evolved - bacterial growth	1.09×10^7 dpm
CO_2 evolved - feeding trial	1.43×10^6 dpm
Total label in all shrimp tissues (includes gills, etc. for all shrimp)	8.10×10^5
Total	1.31×10^7 dpm

Remainder (6.86×10^6 dpm) still in sediment substrate at completion of experiment.

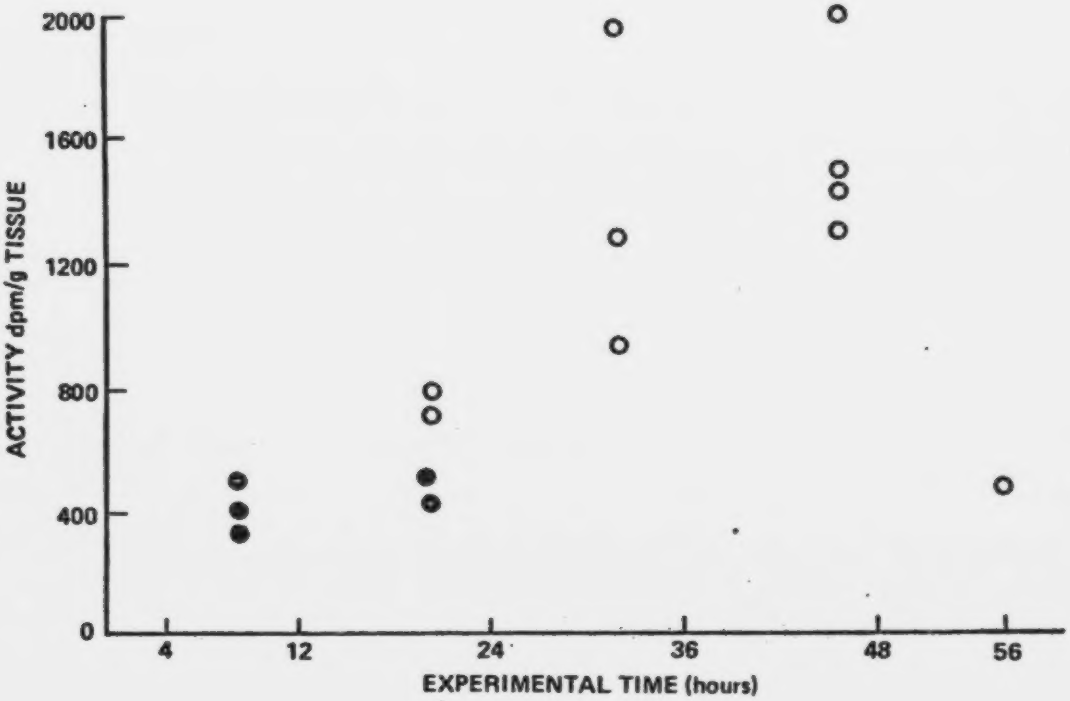


Appendix Figure 5. Activity of individual *Crangon dalli* tissue homogenates.

good levels of activity (4 x 10^4 dpm ml^{-1}). However, shrimp death and problems with the system resulted in failure of the experiment. Several of the experimental animals died and it was necessary to restart the experiment with new ones on the same substrate. These animals in most cases did not feed. Appendix Figure 6 shows the activities of shrimp tissue homogenates for this experiment. It is noteworthy that up to 2000 dpm g^{-1} tissue were recorded for animals that did not feed and had empty guts at the time of collection. Problems with the aeration system resulted in resuspension of the substrate.

DISCUSSION

Results have been presented which suggest that *Macoma* spp. clams assimilated bacteria which had been previously grown on a radioactive label. Although activity levels of the clams were low, the general shape of the curves suggests that label was assimilated, then metabolized, resulting in a loss of activity in the tissues as suggested in the outline (Appendix Figure 1). The use of the labeled bacteria in this experiment appeared to be a satisfactory method and to be relatively free of complications. Although the shrimp experiment using the previously cultured labeled bacteria approach did not work the methods seem satisfactory. More specifically non-feeding animals did not pick up activity, nor did the water or other pools in the experimental set up. Non-feeding animals and death of experimental animals are hazards of experimental biological systems. Hence, this approach appears to be a workable one provided



Appendix Figure 6. Activity of *Crangon dalli* tissue samples. Darkened points are the values of shrimp tissue homogenates which were taken from animals which had observable gut contents. All other points are from shrimp which did not feed.

that activity levels can be adjusted by modifying the amount of label introduction, volume of sediment-detrital mixture and numbers of experimental animals to be dealt with. In the clam experiment, too much dilution of the pregrown bacterial broth by the sediment-detrital mixture took place because the volume of the sediment and the experimental set up was too large.

Results of the mini-ecosystem approach were ambiguous. The first experiment suggested that crangonid shrimp did indeed assimilate the bacteria which had been labeled. High levels of activity were observed after 18-24 hours of exposure to the food source. Again the level of activity began to drop with time as above. This drop in activity was similarly noted for the sediment-detrital food source.

The second experiment using this approach left some doubt as to what was actually being assimilated by the shrimp. In this case animals which had not fed showed activity. This suggests that they were absorbing label from some other source. Further, the problems encountered with this approach were much greater than with the use of the pregrown labeled bacteria. Glassware, tubing, aeration, etc. contributed to the overall complexity of the set up and made for problems during the actual running of the experiment. Resuspension of labeled substrate was a big problem which led to the demise of the control. Labeled substrate found its way into the control chamber thus making activity available to the control animal. However, even if the shrimp showed such levels of activity as these (2000 dpm) it is still suggested from the first experiment that they were absorbing additional label, presumably from bacteria.

The failure of the second experiment poses an interesting question: of what significance is the assimilation of carbon from dissolved sources? This question has frequently been raised for certain types of detrital feeding animals. Recent work has demonstrated that detrital feeding fishes are capable of assimilating detrital non-protein amino acids (Bowen, 1980). Crangonids, residing in a rich organic slurry of sediment and detritus as they do, might be able to take advantage of dissolved organics such as amino acids.

In summary, the previously cultured labeled bacteria approach may be of more value in addressing the simple question of whether or not an animal can assimilate bacterial carbon. The closed system approach as employed here led to problems in interpretation of the results as noted by Conover and Francis (1973). It appears these animals are able to assimilate bacterial carbon, and that additionally they may be able to assimilate dissolved sources of carbon and nutrients. However, from these experiments it is not certain how much occurs from either source.

If further efforts to examine bacterial and dissolved carbon assimilation in these animals were to be initiated, several points are noteworthy in terms of methods. An open flowing seawater system with previously cultured labeled bacteria should be employed. Scintillation cocktails using Biofluor (NEN) should be used for most types of samples with the exception of CO_2. CO_2 can be collected on filter paper soaked in Protosol and counted in the Omnifluor cocktail.

REFERENCES

Adams, S. M. and J. W. Angelovic. 1970. Assimilation of detritus and its associated bacteria by three species of estuarine animals. *Chesapeake Science*, Vol. II, No. 4, pp. 249-254.

Bowen, S. H. 1980. Detrital non-protein amino acids are the key to rapid growth of *Tilapia* in Lake Valencia, Venezuela. *Science* 207:1216-1218.

Conover, R. J. and V. Francis. 1973. The use of radioactive isotopes to measure the transfer of materials in aquatic food chains. *Marine Biology* 18:272-283.

Cummins, K. W. 1973. Trophic relations of aquatic insects. *Annual Review of Entomology* 18:183-206.

Kofoed, L. H. 1975. The feeding biology of *Hydrobia ventrosa* (Montagu) II. Allocation of the components of the carbon-budget and the significance of the secretion of dissolved organic material. *J. Exp. Mar. Biol. Ecol.* 19:243-256.

Moriarty, D. J. W. 1978. Quantitative studies on bacteria and algae in the food of the mullet *Mugil cephalus* and the prawn *Metapenaeus bennettae* (Racek and Dall). *J. Exp. Mar. Biol. Ecol.* 22:131-143.

Rieper, M. 1978. Bacteria as food for marine harpacticoid copepods. *Marine Biology* 45:337-345.

Tenore, K. R. 1975. Detrital utilization by the polychaete, *Capitella capitata*. *J. Marine Research* Vol. 33, 3:261-274.

Tenore, K. R. 1977. Food chain pathways in detrital feeding benthic communities: A review, with new observations on sediment resuspension and detrital recycling. *In* B. C. Coull (ed.), *Ecology of Marine Benthos*, USC Press. pp. 37-53.

Wilcox, J. R. and H. P. Jefferies. 1974. Feeding habits of the sand shrimp *Crangon septemspinosa*. *Biol. Bull.* 146:424-434.